การออกแบบและสร้างช่องระบายความดันเพื่อป้องกันการระเบิดของฝุ่นข้าวมอลท์ในระบบกรองฝุ่นที่ใช้ถุงกรองฝุ่น

Design and Construction of the Deflagration Vent for Preventing the Malt Dust Explosion in the Filter Bag

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Abstract

This study reviews variables and equations in accordance to the NFPA 68 standard used in the design and experiment of the deflagration vent in the filter bag size 5.47 m^3. It suggests improving the filter bag and preventing the loss from the dust explosion Variables : Deflagration Index (K_{St}) = 131 bar.m/s , Static Activation Pressure (P_{stat}) = 0.3 bar , Reduced Pressure **(**P_{red}) = 1 bar , Maximum Pressure P_{max}) = 9.2 bar and Enclosure Volume (V) = 5.47 m^3. From the calculation to find the size of the deflagration vent in accordance with the equations and variables of the standard, the area of the vent is equal to 0.5 m^2. The deflagration vent panel is designed and constructed using aluminum type 1100, 2 mm. thickness, and size 0.82 x 0.82 m^2, by making a groove diagonally as a cross sign at the depth of 0.5, 1.0 and 1.5 mm. The width of the groove is equal to 4 mm., which produced in Thailand. The deflagation vent is designed to be installed so that the bottom edge of the vent is at the same level as the end of the filter bag. The vent duct is then connected and opened up to the outside of the building. The length of the vent duct is 3 m. with one 90 degree bending spot. The hydrostatic test results show only the groove that has the depth of 1.5 mm. can be opened and release pressure at an average pressure of 0.325 bar. The result found that only 1.5 mm. depth groove in not significantly different from 0.3 bar (p-value > 0.05). The result also shows the three types of deflagration vent panel can be opened significantly different (p-value < 0.05). The result shows at the depth of 1.5 mm., it is successful. However, at the depth of 0.5 and 1 mm. it failed to function.

Keywords: Malt dust explosion, Deflagration vent, Filter bag

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Introduction

Dust explosion is another hazard that negatively impacts life and properties. Since 1785 onwards, there had been statistical reporting on dust explosion in foreign countries including the United States of America, Europe, and Africa. Abbasi and Abbasi gathered statistical data of accidents that had occurred from dust explosion during 1785-1979. It was found that dust explosion, totaling 42 times, had created 411 to death and 2,346 injuries (1).

In 1982, Beck (1) gathered dust explosion statistic in Germany during 1965-1980. It was found that there had been more than 357 occurrences of dust explosion.

For beverage producing industries that used grain as raw materials e.g. malt, barley, rice as in the brewing industry where its related processes for storing and preparing raw materials that possibly generate dusts and contain dust explosion risk. This is particularly so in the conveyor section for materials to be stored in silo towers, and moved by conveyors from silo onto production processes. Equipment and machinery used are e.g. filter bag, bucket elevator for moving. This moving caused dust dispersion and explosion risk. It could be noted that Thailand has many industrial groups that use malt as raw materials in the production. This is particularly in the brewing industry using malt as major raw materials and being stored in large quantity. And, during the moving of malt from trucks to be stored in silo, and from silo to be used, every step will use bucket elevators, chains conveyor. All these usages are creating dispersion of dusts, necessitating the use of filter bag for trapping and controlling quantity volume of dust dispersion. These filter bag are the risk of dust explosion. The researcher, therefore, has a need for studying protective measures and decreasing the severity of dust explosion at the filter bag by studying, experimenting, and designing deflagration vent from dust explosion in accordance with the international standards. Results of this study will be used as guidelines for designing and improving deflagration vent in order to protect or mitigate damages from dust explosion.

Limitation of this study is the ratio of the length to the diameter of an enclosure and vent variables (L/D or H/D_{he}) must have a value not exceed to six. For design of the deflagration vents follow up the standards of NFPA 68.

This study is a simulation of an incident occurring condition and being brought to be set up as a test station by using water pressure to substitute the pressure from the explosion of malt dust in the filter bag sized 5.47 m^3 that are used for filtering malt dusts of a brewery factory located in Muang district, Pathumthani province.

Objectives of research

1. To review the variables and equations that are used for calculation the deflagration vent from dust explosion according to the NFPA 68 standards.

2. The deflagration vent size from a malt dust explosion in the filter bag sized 5.47 m^3 has correspond to calculation according to equations of NFPA 68 standards.

3. To design and construction the deflagration vent panel for preventing the malt dust explosion in the filter bag size 5.47 m^3.

4. To search for suggestions on improving the filter bag for preventing the malt dust explosion and applicable thing.

5. To test the function of the deflagration vent panel when the pressure increase to the 0.3 bar.

Hypothesis of research

1. Deflagration vent panel from a malt dust explosion in filter bag size 5.47 m^3 could release pressure up to 0.3 bar when tested by the hydrostatic test method.

2. Deflagration vent panel from malt dust explosion are working at the pressure equal to those calculated when groove to guide on the deflagration vent panel at the depths of 0.5 , 1.0 , and 1.5 millimeters.

Conceptual framework

<u>Independent variables</u>

1. Depth level of groove of vent panels at 0.5 , 1.0 and 1.5 millimeters.
2. Inside pressure of test system at 0.1 , 0.2 , 0.3 , 0.4 , 0.5 and 0.6 bar.

<u>Dependent variables</u>

1. Sizes of deflagration vent from malt dust explosion.
2. Pressure values that make deflagration vent panel to activate from malt dust explosion.
3. Pressure values that make each of deflagration vent panel to activate from malt dust explosion.

<u>Controlled variables</u>

1. Calculating equations for finding sizes of deflagration vent (NFPA 68).
2. Physical characteristic of malt dusts
   - K_{St} value of malt dust is at 131 bar.m.s^{-1}.
   - Diameters of malt dusts $\leq$ 420 micrometers
   - Value of maximum pressure (P_{max}) is at 9.2 bar.
   - Value of MEC is at 0.055 kg/m^3
   - Value of MIT is at 400 °C
   - Value of MIE is at 0.035 J
   - Value of Humidity $\leq$ 5%
3. Volume of filter bag is 5.47 m^3 of the reverse jet type.
4. Width of groove on deflagration vent panel from malt dust explosion is equal to 4 millimeters.

Materials and methods

1. Risk assessment on dust explosions in the malt storage processes

The risk assessment is considering from 5 configurations of an occurrence of dust explosions whether they are corresponded or not. This is done by applying data from the storage processes of malt that are used in the brewing industry whereby the risk assessment on each component will evaluate sub-details according to the Safety Management Manual for Dust Explosible Factory, the Department of Industrial Works, as follows.

Configuration of Dust Explosion Pentagon	Sub-details Being Assessed on each of the Configuration
First Configuration : Fuel	Combustible Dusts Dusts Size < 420 microns
Second Configuration : Dispersion of Dusts	Dispersion of Dust Dust Cloud Concentration $\geq$ MEC (55 g/m^3)
Third Configuration : Dusts Cloud Confinement	Dust Cloud in Confined Area (Filter Bag)
Fourth Configuration : Oxygen	Adequate Quantity of Oxygen in the Air
Fifth Configuration : Ignition Source	Ignition Source has Temperature or $\geq$ MIT or Has Ignition Energy $\geq$ MIE

2. The design and calculation of deflagration vents

This study is an experimental research design related to a design of deflagration vent from malt dust explosion which are of the dust capturing devices (filter bag) within the conveyor transportation processes of malt before being stored in a silo. Such devices will perform the duty of dust filtering that is occurred from the conveyor transportation system of malt, and the contamination, and dirty materials eliminating system etc. The devices that are brought into this study, will be the filter bag device. Presently, there is no deflagration venting system from malt dust explosions. Therefore, there is a risk of causing damages should accidents occur.

The design of the deflagration vents follow up the standards of NFPA 68 for the calculation of the size of the deflagration vents. And, the vent closure is a panel for studying the appropriateness for being brought into use. For such purpose, the test of the functioning of the deflagration vent closure will use 2 methods. They are a calculation and a hydrostatic test where detailed explanations will be made in the test section.

These equation used for calculation the size of deflagration vents follow up the standards of NFPA 68 (2)

$$A_{v0} = 1 \cdot 10^{-4} \cdot \left(1 + 1.54 \cdot P_{stat}^{4/3}\right) \cdot K_{St} \cdot V^{3/4} \cdot \sqrt{\frac{P_{max}}{P_{red}} - 1}$$

$$A_{v1} = A_{v0} \cdot \left[1 + 0.6 \cdot \left(\frac{L}{D} - 2\right)^{0.75} \cdot \exp\left(-0.95 \cdot P_{red}^{2}\right)\right]$$

$$A_{v2} = 1.7 \cdot A_{v1}$$

$$M_T = \left[6.67 \cdot \left(P_{red}^{0.2}\right) \cdot \left(n^{0.3}\right) \cdot \left(\frac{V}{K_{St}^{0.5}}\right)\right]^{1.67}$$

$$A_{vf} = A_{v4} \cdot \left(1 + 1.18 \cdot E_1^{0.8} \cdot E_2^{0.4}\right) \cdot \sqrt{\frac{K}{K_0}}$$

$$E_1 = \frac{A_{vf} \cdot L_{duct}}{V} \quad , \quad E_2 = \frac{10^4 \cdot A_{vf}}{\left(1 + 1.54 \cdot P_{stat}^{4/3}\right) \cdot K_{St} \cdot V^{3/4}}$$

$$K = K_{inlet} + \frac{f_D \cdot L}{D_h} + K_{elbows} + K_{outlet} + \cdots\cdots$$

$$f_D = \left\{\frac{1}{\left[1.14 - 2\log_{10}\left(\frac{\varepsilon}{D_h}\right)\right]}\right\}^2$$

$$A_{vf} = A_{v4} \cdot \left(1 + 1.18 \cdot E_1^{0.8} \cdot E_2^{0.4}\right) \cdot \sqrt{\frac{K}{K_0}}$$

Information constituting a use for design of the deflagration vents comprises.

1. K_{st} has a value of	131	bar . m/s
2. P_{stat} has a value of	0.3	bar
3. P_{max} has a value of	9.2	bar
4. P_{red} has a value of	1	bar
5. Volume (V) has a value of	5.47	m^3

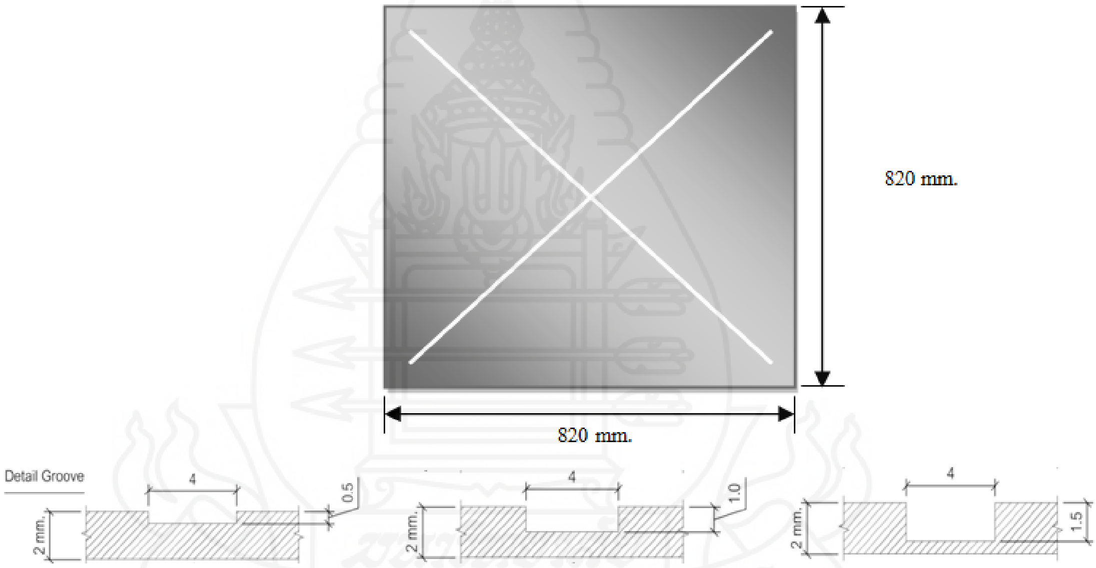
(Note: This information is in accordance to the information used in designing filter bag of the deflagration vents in the same business group, that has the values similar to the study of Dr. M. Roser BGN and FSA, Kapplrodeck and Dr. –Ing.A. Vogl, BGN and FSA, Mannheim and Prof. Dr. S. Radandt, FSA, Bruhl: The value of malt dust K_{St} = 143 bar m/s , P_{max} = 7.9 bar. Because the variable K_{St} , P_{max} are the values that is calculated from an experimental testing, the samples of the dust, all variables has different values.)

3. The design and calculation of deflagration vents panel

The deflagration vent panel are made of aluminium materials type 1100 with thickness 2 millimeters. Made the groove on the surface's depths of 0.5 , 1.0 and 1.5 millimeters into a diagonally crossing shape. The width of grooves is 4 millimeters, weight 3.2 kg/panel. The groove path will end 3 centimeters away from each angle.

The reason of design as follow.

1. Aluminium type 1100 is resistant to corrosion and has a suitable mechanical property.
2. The thickness of 2 millimeters to increase the strength of panel for resistance the effect of operation pressure.
3. The groove on the panel has cross shape for the breaking guide when the pressure reach to design.



depth 0.5 mm. depth 1.0 mm. depth 1.5 mm.

4. The test

For the test of this study, it is an incidental simulation of an increased pressure from water pressure by monitoring the function of the deflagration vent panels that have the size so obtained from the calculation according to the method of standards of NFPA 68 in a form of the vent panel type for studying a responsiveness to the increased pressure. This is done by observing any crack breaking of the vent panel.

As such, from the calculation, the deflagration vent must vent pressure when the pressure is increased to 0.3 bar. This is because the filter bag device will generate wind pressures, while the machine is running, at +0.25 – (-0.25) bar. Therefore, the design has to be made to have the deflagration vent panel to operate at a pressure level higher than that when operating at the normal pressure. This is to prevent an occurrence of wrong purposes of function. The test station of this experiment is brought to be done at the residence of the researcher located at 107, Moo 8, Buapaktha sub-district, Banglen district, Nakhon pathom province. The test station that uses water pressure for testing has the following details.

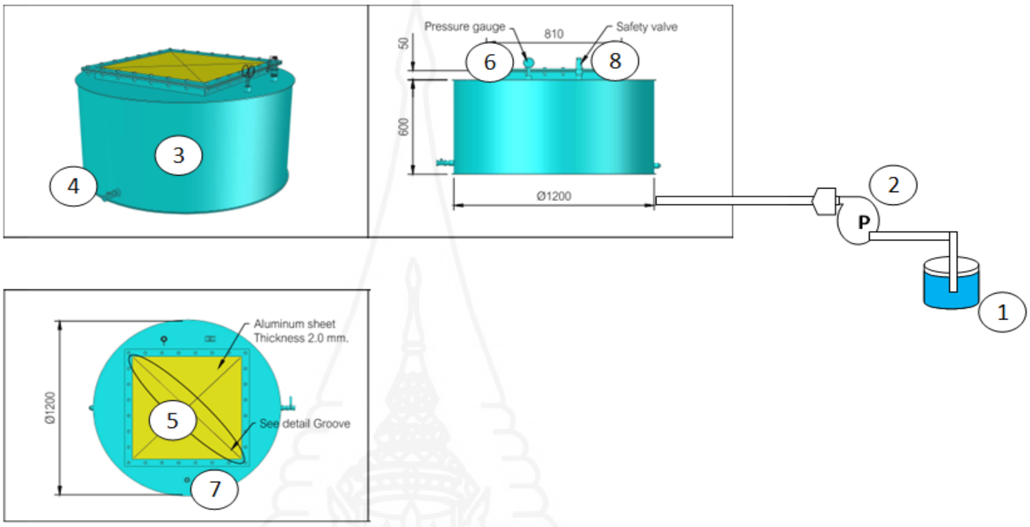


Figure 1 : The test station

Number	Name of Device
1	Water storage for test
2	Water pump for testing tubes with check valve
3	Water tank of cylinder shape at 0.68 cubic meters volume, made of metal at thickness of 3 millimeters in order to function close to the real structure of the filter bag.
4	Valve for releasing water and reducing pressure
5	Deflagration vents panel
6	Pressure gauge
7	Water filling channel
8	Safety valve

4.1 The methodology of hydrostatic test

4.1.1 Filling water into the test station fully leaving a minimum space of air.

4.1.2 Check for leaking of the test station connected tothe pump system and gradually increase the pressure to reach the maximum test pressure of 0.6 bar where the test station must not leak water out by observing into any drop in pressure at the pressure gauge after maintains this test pressure for 10 minutes before inspection.

4.1.3 Install the deflagration vent panel for testing its function at the depth of 1.5 , 1.0 and 0.5 millimeters respectively.

4.1.4 Increase the pressure in the test station gradually until the pressure is reach to 0.6 bar or the deflagration vent panel is breaking.

4.1.5 Before doing the next test, after finishing the recordation of the pressure value and vent the test pressure to atmosphere and the pressure gauge device must be reset to avoid any wrong readings of the pressure value.

4.2 The methodology of measurement the depth of groove

4.2.1 Put the deflagration vent panel on the table.

4.2.2 Cleaning the groove by used cotton wipe the groove to eliminate the dust for reduce the error of depth groove value.

4.2.3 Measure the depth groove with digital vernier caliper for 9 points on the groove of deflagration vent panel. The digital vernier caliper must be perpendicular with deflagration vent panel all the time while measuring.

4.2.4 Record the value of depth groove each point.

4.3 Measurement instrument

4.3.1 Digital pressure gauge

For this study used the digital pressure gauge model DPG8001-300 (OMEGA) For measure the pressure on testing the deflagration vent panel. The specification of digital pressure gauge as follows.

- Record the minimum and maximum of pressure value
- Range 0-21 bar
- 5-digit numeric
- Accuracy 0.25% full scale
- Media temperature -20 to 80 °C
- Operating temperature -20 to 60 °C

4.3.2 Digital vernier caliper

For this study used the digital vernier caliper model 500-193 serial no. 1065742 manufacturer by Mitutoyo. For measure the depth of groove on the deflagration vent panel. The specification of digital vernier caliper as follows.

- Range 0-300 mm.
- Accuracy ± 0.0381 mm.
- Inch/Metric measurement system
- Usage for depth , inside , outside , step

4.4 The machine to construct the deflagration vent panel

4.4.1 Metal fiber laser cutting machine (HSG LASER)

This machine used for cutting the aluminium sheet to construct the deflagration vent panel. The precision of machine equal to $\pm$ 0.05 mm.

4.4.2 Carve machine **(**Robotech RCN 1215)

This machine used for made the groove on the deflagration vent panel at the three level of depth. The machine used pilot endmill diameter size 4 mm. type square to build the groove. The precision of machine equal to $\pm$ 0.01 mm.

5. Statistical analysis

The model for analyzing statistical data is done by using the SPSS program version 11.5 which comprises 2 parts which are.

5.1. Descriptive statistics

Used to explain a characteristic of overall data in the form of the percentages, mean, the maximum value, the minimum value, median, standard deviation, and coefficient of variation.

5.2. Inferential statistics

To use the Nonparametric Test One Sample T-Test for testing the pressure that makes the deflagration vent panel to operate whether the value is equal to 0.3 bar or not.

To use the Nonparametric Test Kruskal-Wallis Test and Descriptive (mean , interquatile) for testing the differences in each group's depth of groove that makes the deflagration vent panel to work at each operational level.

Results

1. The result from calculation the deflagration vent size accordance to NFPA 68 standard.

$A_{vf} = 0.5 \quad m^2$

2. The property of the deflagration vent panel.

Details		Designed	Built
Thickness	(mm.)	2	2
Size	(m^2)	0.71 × 0.71	0.82 × 0.82
Weight	(kg)	2.76	3.2
The width of the groove	(mm.)	4	4
Tensile Strength	(MPa)	124	124
Shear Strength	(MPa)	76	76

3. The experimental results of the deflagration vent panel

3.1 The measurement of the depth of the groove on the deflagration vent panel

The measurement used Digital Vernier Caliper, model 500-193, serial number 1065742 manufacturer by Mitutoyo, a researcher read and record the value all by oneself.

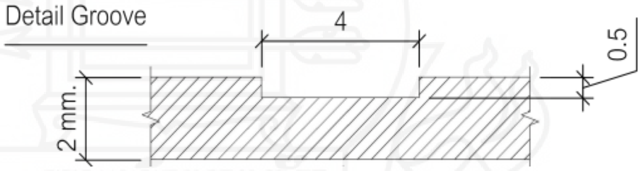
The depth of the groove on the deflagration vent panel.

Sample	**Depth average of the groove (mm.)**		
	0.50	**1.00**	**1.50**
I	0.52	0.98	1.38
II	0.52	1.02	1.73
III	0.52	0.98	1.48
Mean	0.52	0.99	1.53
SD	0	0.02	0.18

3.2 The experimental result of the deflagration vent panel of the groove at the depth of 0.5, 1.0 and 1.5 mm.

A record table of the experimental result of the deflagration vent panel of the groove depth 0.5 mm. is shown below.

Material : Aluminium; type 1100 Thickness 2 mm. Depth of the groove 0.5 mm.

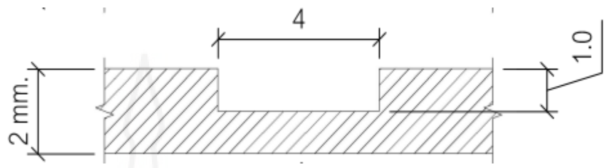


Result of the deflagration vent panel test (depth 0.5 mm.)

Sample	**Test pressure (bar)**		
	Start	**Max.**	**Panel Act**
I	0.023	0.718	not active
II	0.029	0.605	not active
III	0.028	0.608	not active
Mean	0.027	0.644	not active
SD	0.003	0.064	-

A record table of the experimental result of the deflagration vent panel of the groove depth 1.0 mm. is shown below.

Material : Aluminium; type 1100 Thickness 2 mm. Depth of the groove 1.0 mm.

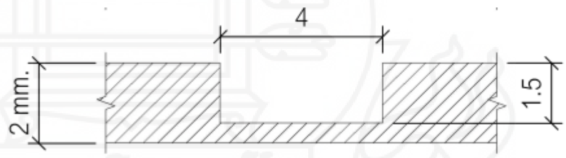


Result of the deflagration vent panel test (depth 1.0 mm.)

Sample	Test pressure (bar)		
	Start	Max.	Panel Act
I	0.029	0.600	not active
II	0.028	0.600	not active
III	0.029	0.602	not active
Mean	0.029	0.601	not active
SD	0.001	0.001	-

A record table of the experimental result of the deflagration vent panel of the groove depth 1.5 mm. is shown below.

Material : Aluminium; type 1100 Thickness 2 mm. Depth of the groove 1.5 mm.



Result of the deflagration vent panel test (depth 1.5 mm.)

Sample	Test pressure (bar)		
	Start	Max.	Panel Act
I	0.024	0.474	active
II	0.023	0.189	active
III	0.023	0.312	active
Mean	0.023	0.325	active
SD	0.001	0.143	-

4. Statistical analysis

The compare mean of deflagration vent panel of the pressure can be opened equal 0.30 bar. The result found that only 1.5 mm. depth groove is not significantly different from 0.30 bar (p-value > 0.05). It mean the deflagration vent panel only 1.5 mm. depth groove can be opened is equal 0.30 bar. This result corresponds to the hypothesis 1.

Compare mean of deflagration vent panel of the pressure can be opened equal 0.30 bar.

Type (mm.)	Mean	S.D.	p*
0.5	0.644	0.064	0.012
1.0	0.601	0.001	< 0.001
1.5	0.325	0.143	0.791

p* for One Sample T-Test

The stimulating the malt dust explosion by hydrostatic test to test the deflagration vent panel among three different depth of the groove. The three types of deflagration vent panel can be opened is significantly different (p-value < 0.05). The result shows at the depth of 1.5 mm. is successful. However at the depth of 0.5 and 1 mm. is failed to function. This finding doesn't correspond to hypothesis 2.

Compare value between three types of deflagration vent panel.

Type (mm.)	n	Median	Iq1-3	p*
0.5	3	0.608	0.605 – 0.718	0.043
1.0	3	0.600	0.600 – 0.602	
1.5	3	0.312	0.189 – 0.474	

p* for Kruskal-Wallis Test

5. Result of risk assessment

5.1 Fuel

The malt dust is the combustible dust. NFPA has categorized dust from agricultural produces that are explosible according to NFPA 499 as follows.

5.2 Dispersion of dusts

The malt dust has dispersion in the filter bag when the process start up.

5.3 Dusts cloud confinement

The dusts cloud of malt dust in the filter bag is the confinement.

5.4 Oxygen

In the filter bag has the sufficient oxygen.

5.5 Ignition source

Ignition source in the process is the electrostatic , friction of machine , welding and other.

Discussion

1. Discussion of study result

1.1 Considering the size of deflagration vent has correspond to calculation according to equations of NFPA 68 standards.

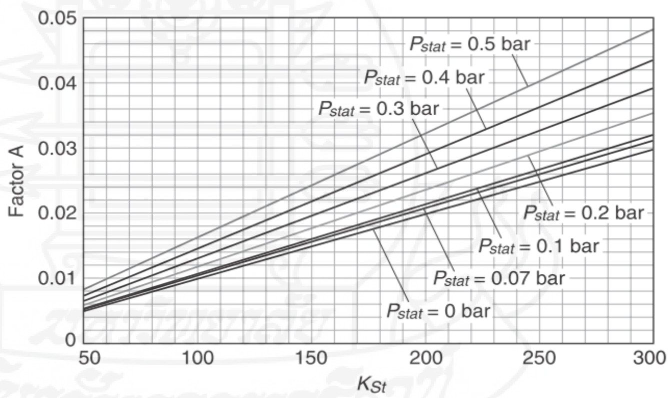
The calculation of the size of deflagration vent from the malt dust explosion in the filter bag, size 5.47 m^3, is correspond to calculation according to equations of NFPA 68 standards. In this study the size of the deflagration vent is equal 0.5 m^2. This is in corresponding to the study of Xingqing Yan, Jianliang Yu (2014). Studied the size of the deflagration vent from Lycopodium dust explosion, size 70 μm, using the method of calculation in accordance to the standard NFPA 68: 2007 and EN 14491: 2006. The different of the size of the deflagration vent depends on the capacity (volume) of the enclosure, type and variable of dust : K_{St} , P_{max} , P_{red} , P_{stat} (3).

The result of the tests of the size of the deflagration vent accordance to the appendix H of the NFPA 68 standard (Prior to calculation of the effects of the vent duct) (2) as follow.

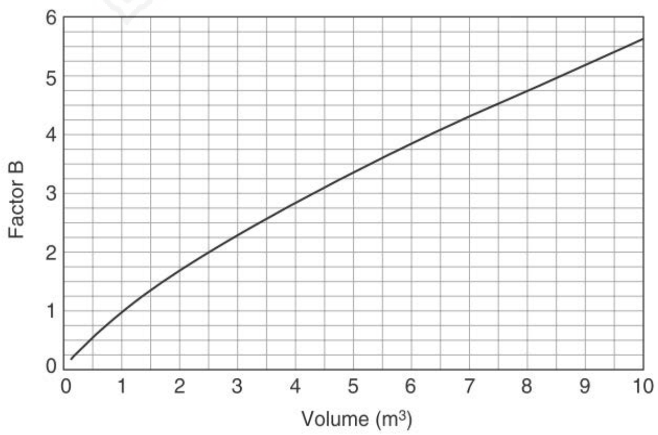
1.1.1 Factor A from the graph **Factor A = 0.016**

when K_{st} = 131 bar-m/s

P_{stat} = 0.3 bar

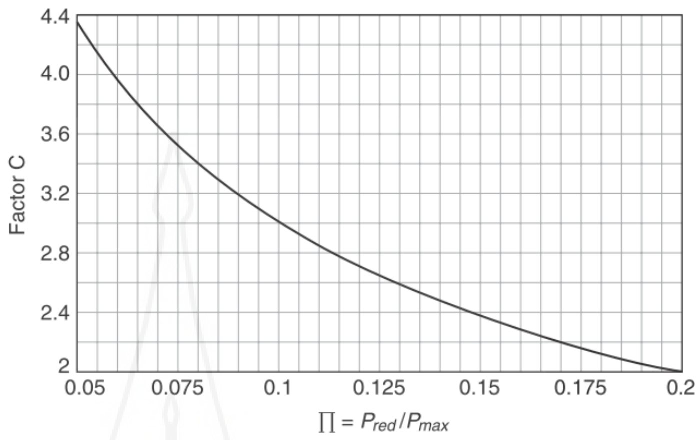


1.1.2 Factor B from the graph **Factor B = 3.5**



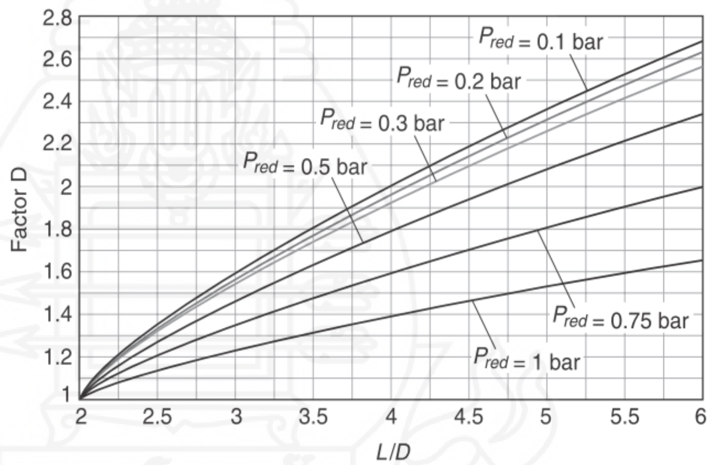
1.1.3 Factor C from the graph **Factor C = 2.8**

when $P_{red} / P_{max} = 1.0/9.2 = 0.11$



1.1.4 Factor D from the graph **Factor D = 1.4**

when L/D = 4.37 and P_{red} = 1.0 bar



The size (area) of the deflagration vent calculated from the graph.

= Factor A × Factor B × Factor C × Factor D

= 0.016 × 3.5 × 2.8 × 1.4

= 0.22 m^2

The size (area) of the deflagration vent calculated from the equation.

$$A_{v0} = 1 \cdot 10^{-4} \cdot \left(1 + 1.54 \cdot P_{stat}^{4/3}\right) \cdot K_{St} \cdot V^{3/4} \cdot \sqrt{\frac{P_{max}}{P_{red}} - 1}$$

$$A_{v0} = 1 \cdot 10^{-4} \cdot \left(1 + 1.54 \cdot 0.3^{4/3}\right) \cdot 131 \cdot 5.47^{3/4} \cdot \sqrt{\frac{9.2}{1} - 1}$$

$A_{v0} = 0.18$ m^2

The size (area) of the deflagration vent calculated from the equations and the graph in appendix H of NFPA 68 standard, the area values are 0.18 and 0.22 m^2 respectively. These areas has a similar value, meaning the area of the deflagration vent of the filter bag is corresponded to the calculation from the equations from the NFPA 68 standard.

1.2 Considering the pressure release value of the deflagration vent panel, when tested by the hydrostatic test method

The deflagration vent panel from the malt dust exposion in the filter bag size 5.47 m^3 is working at the pressure 0.3 bar when tested using hydrostatic test, the result shows that the deflagration vent panel could opened when P_{stat} is equal to 0.3 bar, only the depth equal to 1.5 mm. groove on the panel accordance the statistic analysis to compare mean of deflagration vent panel of the pressure can be opened equal 0.3 bar. The result found that only 1.5 mm. depth groove is not significantly different from 0.3 bar (p-value > 0.05) this corresponds to the hypothesis 1.

To test the deflagration vent panel could be done in 3 different methods, which are from the calculation, hydrostatic test and the test of the explosion. This study doesn't include the test of the explosion as it is considered to be a dangerous and also high cost. The hydrostatic test is comparable to the test explosion, and therefore is used in this study.

This study that could potentially improve the machine (filter bag) to protection the dust explosion in the filter bag size 5.47 m^3. These findings could be used for improving and preventing the loss of the dust explosion is corresponding to the study of Norbert Gibson (1996) study. Gibson concluded that the research in dust exposion are should aim for a shorter period of study so that the industries could use this knowledge to improve their prevention to this very problem straight away – fast and convenience (4).

1.3 Considering the results of the depth of the groove on the deflagration vent panel to their working pressure

The stimulating the malt dust explosion by hydrostatic test to test the deflagration vent panel at all three different depths of the grooves. The three type of deflagration vent panel can be opened is significantly different (p-value < 0.05). The result shows at the depth of 1.5 mm. is successful. However at the depth of 0.5 and 1 mm. is failed to function. This finding doesn't correspond to hypothesis 2.

The results show that by increasing the groove's depth, the thickness and ability of the deflagration vent panel in withstand pressure decreases. This is due to the mechanical properties of the materials and the equation used for calculation the ability of the thin wall structure in withstand the pressure ($p = \frac{2 \times t \times S}{D}$). The study of Barry Dupen; Applied Strength of Materials for Engineering Technology. Chapter 4: Pressure Vessels and Stress Concentrations . v.2 ; 2012 : 23-24 From the equation, the wall thickness (t) of the structure is varied to the working pressure (p) (5).

Considering the shear strength that makes the groove on the deflagration vent panel break as followed.

Shear strength area = the length of the broken groove × the thickness of the groove

= 500 mm. × 0.5 mm.

The reason why selecting value of the length of the broken groove at 500 mm. to use in this calculation due to the hydrostatic test. When the pressure in the system reaches 0.3 bar, the broken grooves are measured the length at the average of 500 mm. After than the pressure will drop down too quickly and that the pump could not be made. Since if this is an actual test for the explosion, the build up pressure could make the groove tears out entirely.

Shear strength = highest shear strength / area of the shear strength

Shear strength that causes the tear = Shear strength × the area of the shear strength

= $76\ N/mm^2 \times 250\ mm^2$

= 19,000 N

To find presure (P) = Force (F) / Area (A)

= $19{,}000\ N / 0.5\ m^2$

= $38{,}000\ N/m^2$

= 0.38 bar

This result shows that the pressure that causes the deflagration vent panel to open from the calculation of the shear strength and the hydrostatic test is equal to 0.38 and 0.3 bar, respectively. These pressure values are not different accordance the statistic analysis to compare mean of deflagration vent panel of the pressure can be opened equal 0.3 bar. The result found that only 1.5 mm. depth groove is not significantly different from 0.3 bar (p-value > 0.05).

Conclusion and Recommendation

1. Conclusion

The purpose of this study was to review the variables and equations used in designed deflagration vent for preventing dust explosion in accordance to the NFPA 68 standard. This study also included the designed deflagration vent and the test's results of the ability of the deflagration vent panel of the malt dust explosion in the filter bag (size 5.47 m^3). The results gives suggestions in developing the filter bag to preventing the loss from the malt dust explosion in an industry.

The results of this study were concluded as followed.

1.1 The calculate the size of the deflagration vent of filter bag size 5.47 m^3 ,accordance the equations and variable of the NFPA 68 standard. The area of the deflagration vent is equal to 0.5 m^2.

1.2 The deflagration vent panel is designed and built using aluminium type 1100, thickness 2 mm., size 0.82 $\times$ 0.82 m^2. The groove was made diagonally as a cross sign at the depth of 1.5 mm. and the width of groove is 4 mm. The deflagration vent panel release pressure would occur when the pressure equal 0.3 bar.

The study show that the calculations of the deflagration vent accordance the NFPA 68 standard could be applied in designing the machine to minimize the loss that could cause by the dust explosion. For this study, the deflagration vent panel that shows potential has to have the 2 mm. thickness, and the groove needs to be made diagonally as a cross sign with the width of 4 mm. and with the depth of 1.5 mm.

2. Recommendation

2.1 Recommendation from the finding of this study

2.1.1 All the instruments used in the study needs to be calibrated prior to use, so that they give an accurate reading result. Also, the person who makes the measurements should also be the one recording the data. For this study the digital pressure gauge and digital vernier caliper passed the calibration prior to use.

2.1.2 The machine that is used for making the groove on the deflagration vent panel should be set up for the highest level of accuracy. The tests should be repeated to increase the sample size for accuracy.

2.1.3 The calculation of the size of the deflagration vent could potentially be applied and used as an improvement to other machines that the prevention of the dust explosion to minimize the loss of the dust explosion.

2.1.4 In this study, aluminium that is used for making the deflagration vent panel is the material that could be found in Thailand. This therefore could minimize the import of the deflagration vent panel from overseas.

2.2 Recommendation for the further study

2.2.1 The standard used in the study

In this study, the NFPA 68 standard is used in the design for the size of the deflagration vent. This standard is one of the standards use currently. The other standards could also be used, such as EN 14491, VDI 3673 or NFPA 68 new version. Furthermore, the study of dust explosion in others industries, others machine and others combustible dust should also be studied.

2.2.2 The designs

The designs of the deflagration vent panel and the vent ductmay be used other design, should also considered the effects of the designs to the machine’s efficiency, accumulate of the dusts as well as others standard to related the production. The tests are required prior to the installation.

The test of each exposible dust for analyse the controlled variables to calculation and design the deflagration vent panel. It make the highest level of accuracy.

2.2.3 Materials used for making the deflagration vent panel

For the materials used in this study is aluminium type 1100, which produced in Thailand. Others types of aluminium or others materials, such as stainless steel, can be used as a substitute. The groove made on the deflagration vent panel could give the opening guide of the deflagration vent panel. The deflagration vent panel could also be adjusted in the width, and the depth of the groove. However, it is important to consider tests prior to the installation, the stability of the materials that would not lead to contamination to the product, etc.

2.2.4 The methods to test the deflagration vent panel

In this study, the hydrostatic test is used for testing the deflagration vent panel. If, however, there is a support to build the practical system that could be used in testing the dust explosion in Thailand, that will increase the accuracy of the test of the deflagration vent panel. That could also support a great improvement in the dust explosion research. Currently the analysis and the practical tests of the dust explosion could only be done oversea and high cost. Furthermore, in Thailand many industries are needed of the preventive technologies of the dust explosion and they have to importing the technology from overseas.

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