Style Guide for Authors Preparing Papers for

6th International Conference for Conveying and Handling of Particulate Solids (CHoPS)

and

10th International Conference on Bulk Materials Storage, Handling & Transportation (ICBMH)

3–7 August 2009, Brisbane, Queensland, Australia
www.chops2009.org.au

This is the style guide for preparing and submitting manuscripts for the Conference Proceedings. Please follow the instructions in this style guide as closely as possible, so that your paper can be reproduced with a minimum of difficulty. An example of a paper prepared according to this style guide is attached.

1. GENERAL PAPER SUBMISSION REQUIREMENTS

General information and requirements applicable to all papers are summarised below.

- Each paper to be published in the Conference Proceedings must be presented in person at the Conference by one of the authors.
- All peer-reviewed and "non" peer-reviewed papers must be completed according to this style guide (see Sections 1.1 and 1.2).
- **A Copyright Permission form (supplied separately) also will need to be completed, signed, dated (for each paper) and scanned/emailed or faxed to the Conference Chair**:
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  Note: this Copyright Form must be received by the same deadline for the receipt of the final Full Papers (after corrections, etc).
- All papers are to be submitted in soft copy only (PDF, 3 MB maximum file size per paper) and must be emailed to the Conference Chair by the designated deadline – refer to the Conference website for further details. Authors with more than one paper must submit their papers separately (i.e. one paper per email). A Copyright Form also must be completed/signed/dated for each paper and sent to the Conference Chair (see above).
- Note: PDF is preferred and recommended to maintain formatting, fonts, etc; the organising committee accepts no responsibility for errors/changes resulting from opening/printing documents with different applications, formats, fonts, symbols, figures, etc.
- In general, all papers must be professional and must not contain any form of advertising, "sales pitching", inappropriate content, etc. The Conference Chair reserves the right to edit or even reject any paper for such reasons.
- All accepted final Full Papers will be published in the Conference Proceedings, which will be distributed on a USB pen drive during Registration.

1.1 Peer-Reviewed Papers (optional)

Authors can elect to have their papers peer-reviewed by an independent panel of referees (i.e. to satisfy academic/government accreditation purposes). Each accepted/corrected peer-reviewed paper will be identified accordingly in the Conference proceedings.

Each draft Full Paper to be submitted for peer review must be prepared according to this style guide and emailed to the Conference Chair by the designated deadline, which is somewhat earlier than that for standard ("non" peer-reviewed papers) – see Section 1.2. Refer to the Conference website for further details.

Note: any papers that are not received by the relevant deadline/s or do not comply with this style guide will be "transferred" to the "non" peer-review category (see Section 1.2). The relevant author/s will be contacted accordingly.

Further information and requirements for peer-reviewed papers are summarised below.

- Peer-reviewed draft Full Papers that are found acceptable in their present form will be held as final Full Papers for direct publication in the Conference proceedings.
- For any papers identified as requiring correction or revision, the corresponding author/s will be notified accordingly, and a soft copy of the corrected paper must emailed to the Conference Chair by the designated deadline. Also, in a covering letter with the corrected paper, the authors must summarise the changes undertaken as a result of the peer-review process (and give reason(s) for not following any of the change(s) suggested by the review panel).

1.2 Standard ("Non" Peer-Reviewed) Papers

Authors can submit their papers without going through a peer-review process (see Section 1.1). Most industry papers do not require peer-review and hence, would fall into this category.

Each draft "standard" Full Paper must be prepared according to this style guide and emailed to the Conference Chair by the designated deadline. Refer to the Conference website for further details.

In general, all "standard" papers that are submitted by the designated deadline and also comply with this style guide will be published directly in the Conference Proceedings. The Conference Chair reserves the right to edit (or even reject) any paper containing advertising, etc, as explained previously under general submission requirements. The relevant author/s will be contacted accordingly.

2. PAPER CONTENT

Your manuscript should include the following parts, in the order listed below.

- Paper title.
- Author(s) – please indicate presenting author with an underline.
- Company/organisation details of each author.
- Abstract (100 to 200 words).
- Introduction (200 to 400 words).
- Main body (including equations, figures, tables, etc).
- Conclusions.
- Acknowledgements (if applicable).
- Nomenclature (if applicable).
- References.

2.1 Abstract

Your abstract should be 100 to 200 words. It should summarize the principal findings presented in the paper, and should give readers enough information to determine if they wish to read the whole paper. Do not include tables, figures, equations or references in the abstract. Leave two blank lines after the Abstract.

2.2 Introduction

The introduction of your paper should state in approximately 200 to 400 words the nature of the project or problem you are addressing and why you are studying it. It should introduce the reader to the paper and provide background information about the work and its significance.

2.3 Main Body

The body of your paper should follow the introduction and should include experimental methods and results (if applicable), discussion, etc. The results and discussion sections may be combined. Within the body of your paper and a given sub-section, you can set up as many subheadings as you need. You can also include numbered and/or bulleted lists, as well as bold and italic type and superscript and subscript characters.

2.4 Conclusions

This section should highlight key findings and compare the results of your work to others as appropriate. Conclusions are often written in present tense and should be based on the evidence in your paper. New material should <u>not</u> be introduced in this section.

2.5 Acknowledgements

If your paper contains acknowledgements, they should be placed after the conclusion but before the references.

2.6 Nomenclature

All symbols used in the paper must be summarised in alphabetical order. Appropriate units must be included.

2.7 References

References should be cited within your manuscript with Arabic numerals and square brackets, such as [12], [13-15], [16], etc. The reference section should follow immediately after the nomenclature section. List your references numerically as they appear in your manuscript (not alphabetically). Refer to the attached Sample Paper for examples of the referencing method and format.

3. PAPER FORMAT

3.1 Paper Size, Length, Margins, Page Numbers

- Paper Size: A4 (21 cm wide, 29.7 cm high).
- Paper Length: six (6) pages (maximum), including all figures, tables, appendices, etc.
- Margins: 2.5 cm (top, bottom, left and right).
- Page Numbers: Do NOT insert page numbers on your manuscript – this will be done by the Editor on the Finals Papers before publication.

3.2 Fonts, Equations, Tables and Figures

Please use the attached Sample Paper as a guideline for:
- Size and type of fonts (for headings, etc);
- Line spacing;
- Equation format and numbering;
- Location and format of figures and tables.

4. CONCLUSIONS

This style guide describes how to prepare and submit your manuscript so that it can be published professionally in the Conference Proceedings. If you do not adhere to the formatting instructions in this style guide, your submission may not be published in any form. Each final Full Paper published in the Conference Proceedings must be presented in person at CHoPS+ICBMH by one of the authors.

We thank you in advance for your cooperation.

If you have any questions about this style guide, please contact:

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Dust Explosion Hazard Considerations for Materials Handling Plants

Times New Roman 14pt **Bold**

Peter W. Wypych[1] **and Harry J. Citizen**[2]

Times New Roman 12pt Regular

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Times New Roman 10pt (for remainder of paper)

ABSTRACT Most powders and dusts found in industry can explode when mixed with the right amount of oxidant. Despite a considerable amount of information available on dust explosions, the impact or relevance of this information on materials handling plants and processes often is not discussed in great detail. This paper addresses some of the more important explosion hazard considerations that should be made when designing, analysing or auditing powder handling systems and processes. Relevant dust characterisation is an essential part of this process and involves the determination of: particle size distribution; particle density; particle shape; moisture content; humidity; temperature; electrostatic, cohesive and adhesive properties. Despite the similarities with gas explosions, dust explosions can be quite different and it is important to be aware of these differences for design and evaluation purposes. The risk and severity of dust explosions can be reduced by understanding the relevant mechanisms inside each process and in particular, minimising the generation and turbulence of dust.

1. INTRODUCTION

For a dust cloud to explode: the dust must be explosible and airborne; the dust cloud must be present in an atmosphere capable of supporting combustion and in contact with an ignition source of sufficient energy; the size distribution of airborne particles must be capable of supporting flame propagation; the concentration of dust particles must be between the LEL (typically 20 to 100 g m^{-3}) and the UEL (typically > 2000 g m^{-3}).

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2.5 cm Margin

Whilst a considerable amount of data and information on dust explosions can be found in the literature (e.g. research papers, catalogues, standards, codes), the impact or relevance of this information on materials handling plants and processes often is not discussed in great detail. The main aim of this paper is to describe some of the more important considerations that should be made when designing, analysing or even auditing powder handling systems or processes. Particular emphasis is placed on:

- the characteristics of dust explosions, especially in comparison with gas explosions;
- the importance of dust characterisation and explosion testing;
- the methods used to size explosion venting (pressure relief) systems;
- minimising the generation and turbulence of dust for the purpose of reducing the risk and severity of dust explosions.

The two main methods of explosion hazard control are explosion prevention (e.g. preventing formation of explosible dust clouds, removing all possible ignition sources, creating an atmosphere that cannot support combustion) and explosion protection (e.g. venting, suppression, containment and/or isolation). Quite often it is difficult to guarantee explosion prevention (e.g. due to equipment/instrumentation failure and/or human error). Explosion protection usually is pursued to protect personnel and minimise plant damage.

2. DUST EXPLOSION CHARACTERISTICS

Despite the similarities with gas explosions, dust explosions can be quite different. For example:

- Combustion mainly occurs at the surface of the material exposed to oxidants. If these solids are converted to fine airborne particles, there is an enormous increase in surface area and hence, rate of burning;
- In gas-air mixtures, the molecules are very close to each other, whereas in dust-air mixtures the gas molecules are close to particles which are relatively large and heavy;

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- The inertial forces of particles can be quite significant and result in different fuel concentration gradients;
- It is possible for the blast wave from an initial or primary explosion to disturb and re-entrain settled layers of dust on nearby equipment and structures, resulting in a secondary explosion;
- If a strong primary explosion occurs in a pipe, it is possible for the flame front to accelerate through the turbulent mixture to supersonic speeds. This situation is referred to as detonation.

3. DUST CHARACTERISATION

The above phenomena and descriptions indicate the importance of dust properties and characterisation. Current trends and experiences indicate the following major influential properties.

- Particle size distribution: evaluating amount of "fines" and explosion severity, Figure 1, although in some cases this may be difficult (e.g. flaky/fibrous dusts).
- Particle density and particle shape: estimating settling rates of particles and particle concentrations in storage bins, etc; evaluating filtration efficiency; evaluating specific surface area and explosion severity.
- Moisture content, humidity and temperature: affecting explosibility characteristics; possible drying out of powders when using dry air for pneumatic conveying; powders produced/processed at elevated pressures/temperatures affecting explosibility.
- Electrostatic, cohesive and adhesive properties: possible build-up of powder inside dust collectors and even explosion vent panels; dust layers can suddenly become airborne and increase explosion severity; quantifiable via flow property test work [1]; particles impacting or rubbing against filter bags causing electrostatic charging and possible spark ignition of dust clouds.

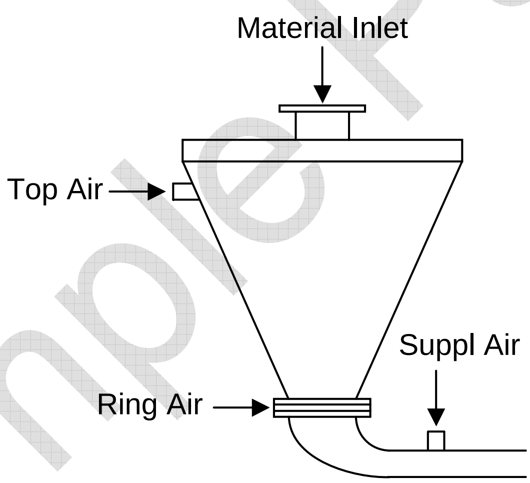

Figure 1 Single-Slug Blow Tank Feeder

3.1 Explosion Testing

Explosion test data, such as the dust explosibility characteristic K_{st} (bar m s^{-1}), as defined in Eqn. (1), LEL, etc, are obtained under controlled laboratory conditions using standard 20 litre or 1 m^3 explosion vessels [2,3]. Special feeding mechanisms are employed in these vessels to ensure homogenous dust-air mixtures and minimal turbulence levels at the point of ignition. However, such conditions seldom occur in industry.

$$K_{st} = \left(\frac{dP}{dt}\right)_{max} V^{\frac{1}{3}} \qquad (1)$$

For the above reasons, it is essential to understand and appreciate what happens to the product and dust inside each process or during each operation. Such knowledge will assist in minimising the risk of explosion hazards and assist in designing the explosion tests to simulate on-site conditions as closely as possible, in terms of process parameters, turbulence levels, etc. In this way, the explosion data can be scaled up with confidence. For this purpose, all pertinent parameters should be recorded accurately (e.g. particle size distribution, particle density, moisture, initial pressure/temperature, etc, as described above).

4. EXPLOSION VENTING

Pressure relief venting is the most common method of explosion protection. The principles of explosion venting are depicted in Figure 2. P_{max} is the maximum unvented explosion pressure and has been measured as high as 15 bar g. Hence, P_{max} usually exceeds the design pressure (P_{des}) of most storage bins, dust filters, dryers, etc. By fitting a vent with a given opening or bursting pressure (P_{stat}), the resulting increase in pressure can be similar to Curve B or C, depending on the size of the vent. The maximum pressure achieved under these conditions is referred to as the reduced explosion pressure, P_{red}. Note in some situations (e.g. self-closing explosion doors), it is possible for the explosion pressure to go negative before returning to atmospheric conditions (e.g. Curve D).

The four basic methods of vent sizing are the Kst Nomograph Method [2], the St Group Nomograph Method [2], the Radandt Nomographs [2] and the Scholl Equation [4], which also is included in VDI 3673 [5].

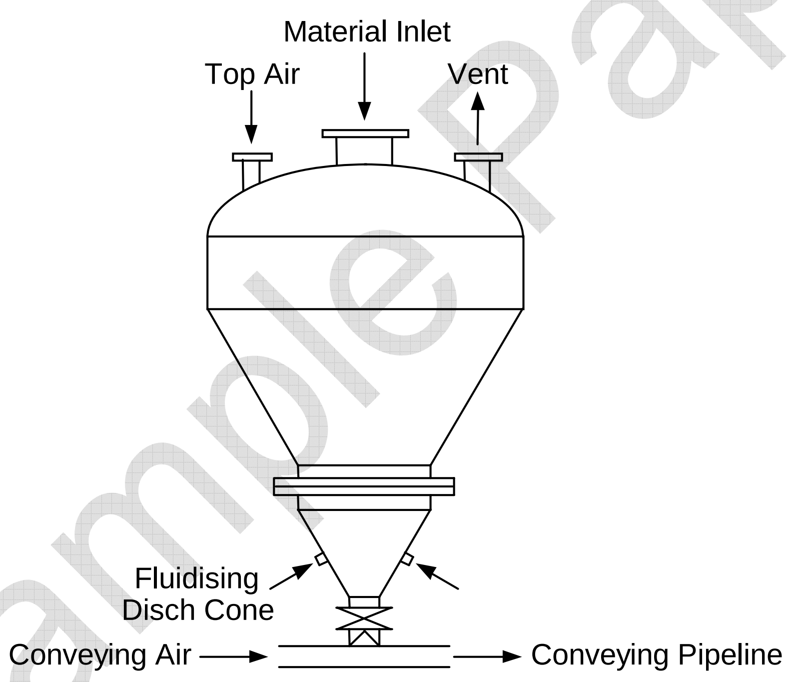

Figure 2 Bottom-Discharge Blow Tank Feeder

It should be noted that: these methods are subject to several limitations; equations also are provided [6] to approximate the K_{st}, St and Radandt Nomographs; certain industrial situations may require modifications to these techniques - some of the main issues are discussed later in this paper; despite its apparent simplicity, dust explosion remains a complex and controversial subject [7]; the relevant literature [2-8] should be consulted for further details. The following case study demonstrates the different vent sizing methods.

4.1 Case Study

A 16 m^3 storage bin is to be fitted with a dust collector with an internal volume of 2 m^3. A venting panel with an opening pressure of P_{stat} = 10 kPa-g is to be sized to handle a dust with K_{st} = 150 bar m s^{-1} and P_{max} = 9 bar-g. The pressure strength of the storage bin is 45 kPa-g and the filter 70 kPa-g. Using all four sizing techniques, including the corresponding approximate equations [6], the vent area calculations are summarised in Table 1.

Table 1 Summary of Vent Area Calculations (V = 18 m^3, P_{des} = 45 kPa-g, P_{red} = 30 kPa-g)

Sizing Method	Calculated Vent Area (m^2)
K_{st} Nomograph [2]	1.50
K_{st} Nomograph Equation [6]	1.42
St Group Nomograph [2]	1.60
St Group Nomograph Equation [6]	1.56
Radandt Nomograph [2]	0.90
Radandt Nomograph Equation [6]	0.90
Scholl Equation [4]	0.77

It can be seen the vent area estimations vary from A_v = 0.77 to 1.6 m^2. Such discrepancies can occur frequently in this area of work and can throw doubt over the validity or accuracy of available sizing techniques. Without having specific and justifiable reasons to do otherwise, the K_{st} Nomographs should be employed for design and evaluative purposes (e.g. $A_v \approx 1.5$ m^2 should be considered for the above application).

The ideal and preferred venting arrangement is one where the explosion is vented directly to atmosphere (i.e. without any obstruction or restriction). However, this often is not possible in many industrial plants and the common practice here is to attach a pipe or duct to the venting device and direct the deflagration to a safe place, usually atmosphere. Extreme caution must be exercised in the design and application of such systems.

5. MINIMISING GENERATION AND TURBULENCE OF DUST

In many instances, it may be possible to reduce the risk and severity of dust explosions by minimising the generation and turbulence of dust. This can be achieved by understanding the fundamental mechanisms of dust generation (referred to as pulvation) and using this information in materials handling plant design. For example, in a falling stream of material, it has been found [9]: the main core of falling powder is surrounded by a turbulent layer of fine dust, which escapes easily into the surrounding air; air is entrained in the falling stream of dilating powder; the impact zone is a highly turbulent region where the entrained air is ejected into the atmosphere at relatively high velocity and carries with it a large amount of fine dust; considerable reductions in dust concentration and turbulence can be achieved by minimising drop height.

The above situation is exacerbated for pneumatically filled bins that use conventional central filling. Here, the velocity at impact can be quite high, especially when the material reaches high level. The extent and severity of dust generation can be reduced by employing a large “drop-out box” by increasing the diameter of pipe and/or incorporating a large-diameter tee-bend at the end of the pipeline. Further reductions in dust loading may be possible by using a stepped pipe, tangential entry and internal shroud. For example, Hauert et al. [10] found that the P_{red} values for the tangential pneumatic filling of wheat flour and corn starch were 3 to 5 times smaller than those obtained with central filling.

Significant increases in dust also can occur during the dilute-phase transport of granular particles. The air velocity required to maintain the suspension of particles depends on many factors and usually occurs in the range 15 to 40 m s^{-1}. These relatively high velocities can cause particle attrition and a significant increase in dust levels and electrostatic charge generation. Hence, minimising velocity should be considered as an initial option for dilute-phase systems. However, the extent and success of this option depend on many factors (e.g. particle properties, pipeline configuration, system capacity, minimum transport, etc).

Significantly greater reductions can be achieved by selecting the dense-phase (non-suspension) mode of flow. Here the particles are conveyed either in fluidised dense-phase (e.g. for air retentive powders, such as flour and starch) or low-velocity slug-flow (e.g. for granular products, such as wheat and sugar).

Note: for material “mixtures” that contain numerous ingredients (e.g. sugar, cocoa, etc), it is logical to have the mixture tested and determine accurate values of P_{max}, K_{st}, etc. However, the handling and processing of such mixtures also should be evaluated with the aim of establishing possible segregation effects. Hence, it may be necessary to check the explosibility characteristics of each ingredient and consider the worst case scenario. However, to justify this more conservative approach, it is necessary to obtain the size distribution and density of each ingredient, and also determine the relevant mechanism(s) of segregation.

6. CONCLUSIONS

Flame propagation depends strongly on dust cloud and particle properties. Hence, dust characterisation is an essential element of dust explosion hazard control. Certain industrial situations may require modifications to existing explosion vent sizing techniques. In particular, extreme caution must be exercised in the design and application of vent ducts.

The severity of dust explosions can be reduced by minimising the generation and turbulence of dust. Some options include reducing drop height, stepping conveying pipes and selecting the dense-phase mode of transportation.

7. ACKNOWLEDGEMENTS

The authors would like to acknowledge the financial support provided by the Australian Research Particle Council for the characterisation section of this paper. The authors also would like to acknowledge and thank: Woopwoop Technology Pty. Ltd. for the financial support and guidance provided towards the other sections of this paper; the University of Woopwoop for the scholarships that allowed this research to be pursued in detail.

8. NOMENCLATURE

A_v	Explosion vent area, m^2
d_{50}	Median particle diameter, µm
$(dP/dt)_{max}$	Maximum rate of pressure rise, bar s^{-1}
K_{st}	Dust explosibility characteristic, bar m s^{-1}
LEL	Lower explosibility limit, g m^{-3}
P	Pressure, kPa-g
P_{des}	Pressure strength of weakest component in contact with dust cloud, kPa-g
P_{max}	Maximum unvented explosion pressure, kPa-g
P_{red}	Reduced explosion pressure under vented conditions, kPa-g
P_{stat}	Opening or bursting pressure of explosion relief panel, kPa-g
t	Time, s
UEL	Upper explosibility limit, g m^{-3}
V	Maximum possible “dirty” volume, m^3

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