20 Liter Limiting Oxygen Concentration Test (LOC)

INTRODUCTION

The explosive behavior of dusts can be described by the maximum explosion pressure (P_{max}), the maximum rate of explosion pressure rise (K_{St}), the minimum explosive concentration (MEC) and the maximum oxygen concentration to prevent explosions. The limiting oxygen concentration (LOC) is the highest volume percent of oxygen in an oxygen/nitrogen atmosphere that will prevent the propagation of a combustion-deflagration wave in a closed vessel. This data may be used to establish safe process operating conditions.

BACKGROUND

The potential severity of a dust explosion is quantified by measurement of the pressure and rate of pressure rise due to the explosion. These measured parameters are a function of:

- The physical and chemical properties of the dust (particle size distribution and chemical composition);
- The concentration of dust in the dust/air mixture;
- The homogeneity and turbulence of the dust/air mixture;
- The type, energy and location of the ignition source;
- The geometry of the vessel in which the explosion is occurring;
- The initial pressure and temperature of the dust/air mixture.

Therefore, it is important to use a standard laboratory test method to measure these explosion parameters.

A typical pressure time curve from a dust explosion in a 20 liter chamber is shown in Figure 1. $P_{ex,a}$ is maximum absolute pressure observed during the course of the explosion. P_{ex} is the maximum gage pressure observed during the course of the explosion. Similarly, $(dp/dt)_{ex}$ is the maximum rate of pressure rise during the explosion. As noted above P_{ex} and $(dp/dt)_{ex}$ vary as a function of several parameters. In the test method used; homogeneity, turbulence, energy type, location of the ignition source, vessel geometry, and initial conditions are kept constant. The effect of varying concentration on P_{ex} and $(dp/dt)_{ex}$ is then observed for a given dust.

Also shown in Figure 1 is a typical pressure vs. time curve produced by the standard ignition source. As oxygen concentration is lowered, P_{ex} is also lowered and becomes the same order of magnitude as the pressure due to the ignition source, $\Delta P_{igniter}$. $\Delta P_{igniter}$ is determined by performing a test in the absence of dust. In determining the minimum oxygen concentration to prevent combustion, the effect of the ignition source is taken into consideration by determining the relationship between oxygen concentration and the Pressure Ratio (PR). The pressure ratio (PR) is calculated using the following equation.

$$PR = \frac{P_{ex,a} - \Delta P_{igniter}}{P_{ignition,a}}$$

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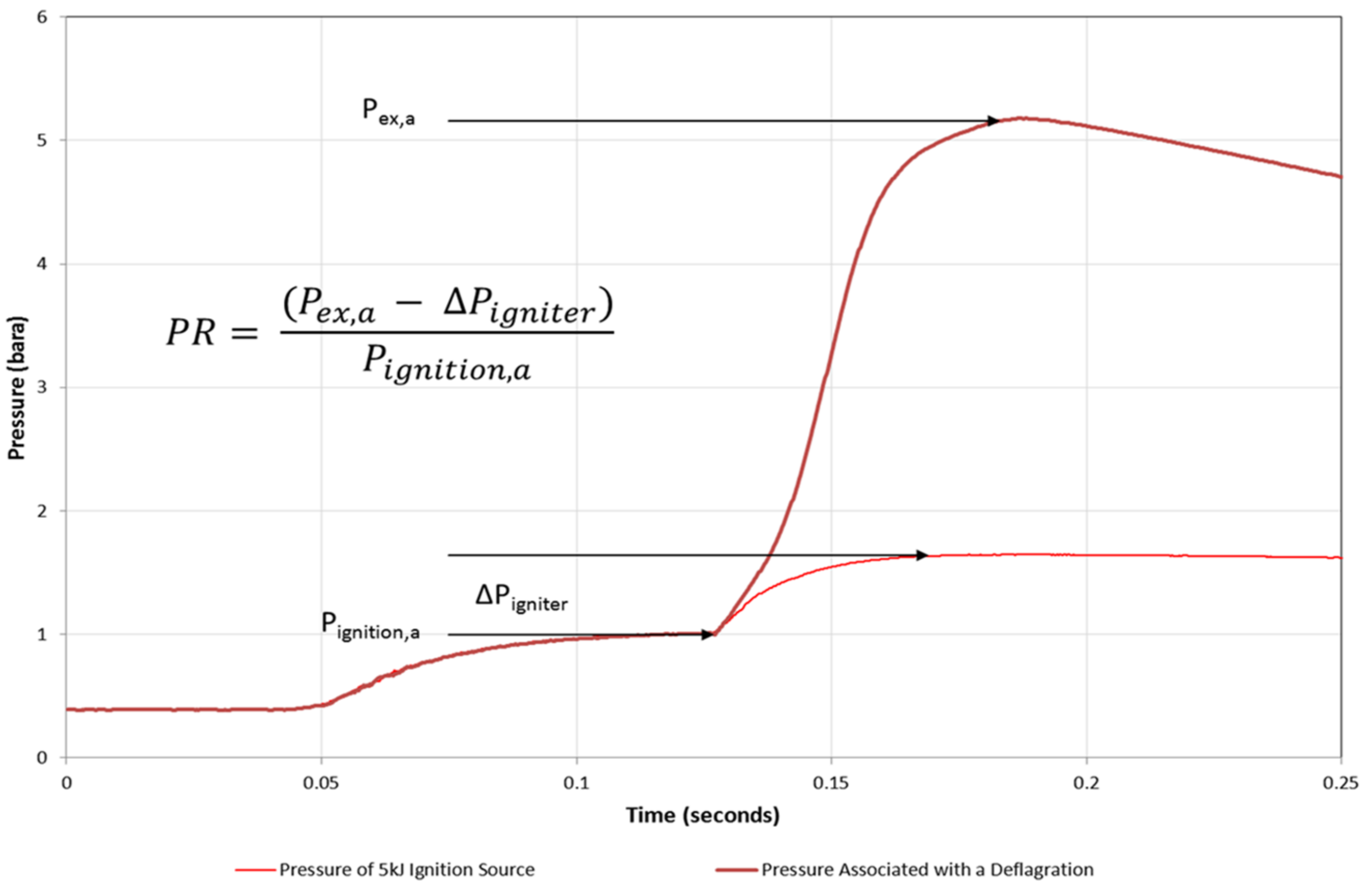
Where:

$P_{ex,a}$ = Maximum absolute explosion pressure
$\Delta P_{igniter}$ = Pressure increase due to the ignition source
$P_{ignition,a}$ = Absolute vessel pressure at the time of ignition

This pressure ratio represents a 100% pressure increase over the initial test pressure. This criterion is used for all tests conducted.

Figure 1: Pressure Ratio Ignition Criterion



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EXPERIMENTAL

A schematic of the apparatus used to measure the dust explosion parameters in compliance with ASTM E2931 is shown in Figure 2. The explosion chamber used is a 20 liter sphere containing a dispersion nozzle. The dispersion nozzle is connected to a sample loading cylinder and a 0.6 liter air discharge vessel. During an experiment, dust is placed in the loading cylinder and the air discharge vessel is pressurized to 290 psig using air and nitrogen. The dust is dispersed through the holes of the dispersion nozzle into a partially evacuated explosion chamber by activating the ball valve in between the discharge vessel and the sample cylinder. The resulting dust cloud is ignited with a chemical igniter placed at the end of the ignition leads. The ignition source is located at the center of the spherical explosion chamber. The oxygen content is varied by controlling the composition of the O_2/N_2 mixture in the 0.6 liter discharge vessel and the partially evacuated explosion chamber. Though the composition is varied, the evacuation level of the explosion chamber and the pressure of the discharge vessel are not varied from test to test.

Two pressure transducers are used to observe the pressure history of the explosion. Proprietary operating software is used to control the operation of the ball valve and the ignition of the dust cloud, as well as to collect pressure data from the transducers during each test. The time delay between injection and ignition is held constant in accordance with previous vessel calibrations. At the time of ignition, the dust cloud is at room temperature (~25° C) and a normal pressure of 1.0 bara ±5%. A filtered exhaust is attached to the chamber to allow safe post-explosion cleanup of the chamber.

The general procedure for the experiments are shown below:

A. A weighed amount of dust is placed in the loading cylinder.
B. A chemical igniter is placed at the center of the chamber.
C. The chamber is sealed.
D. The explosion chamber is partially evacuated and then filled with an appropriate composition of O_2/N_2.
E. The discharge vessel is pressurized to 290 psig with the appropriate composition of O_2/N_2.
F. The operating software synchronously controls injection, ignition, and data acquisition during the combustion process.
G. Data is processed and test logs are updated.
H. The chamber is vented through the filtered exhaust and flushed with air.
I. The chamber is opened and cleaned thoroughly prior to the next test.

The procedure to obtain a specific oxygen concentration is described in detail in Table 1. Tests are conducted at a range of oxygen concentrations and dust concentrations to determine the relationship between oxygen concentration and the Pressure Ratio (PR). Dust concentrations are varied to find the lowest oxygen level needed to support combustion. A replicate test is performed at the optimum dust concentration using the highest oxygen level in which an ignition was not observed. Duplicate tests are conducted at dust concentrations on both sides of the optimum. These tests are conducted at the highest non-ignition oxygen level. The reported LOC value is the average of the highest oxygen concentration where non-ignitions are observed and the lowest oxygen concentration where ignitions are observed.

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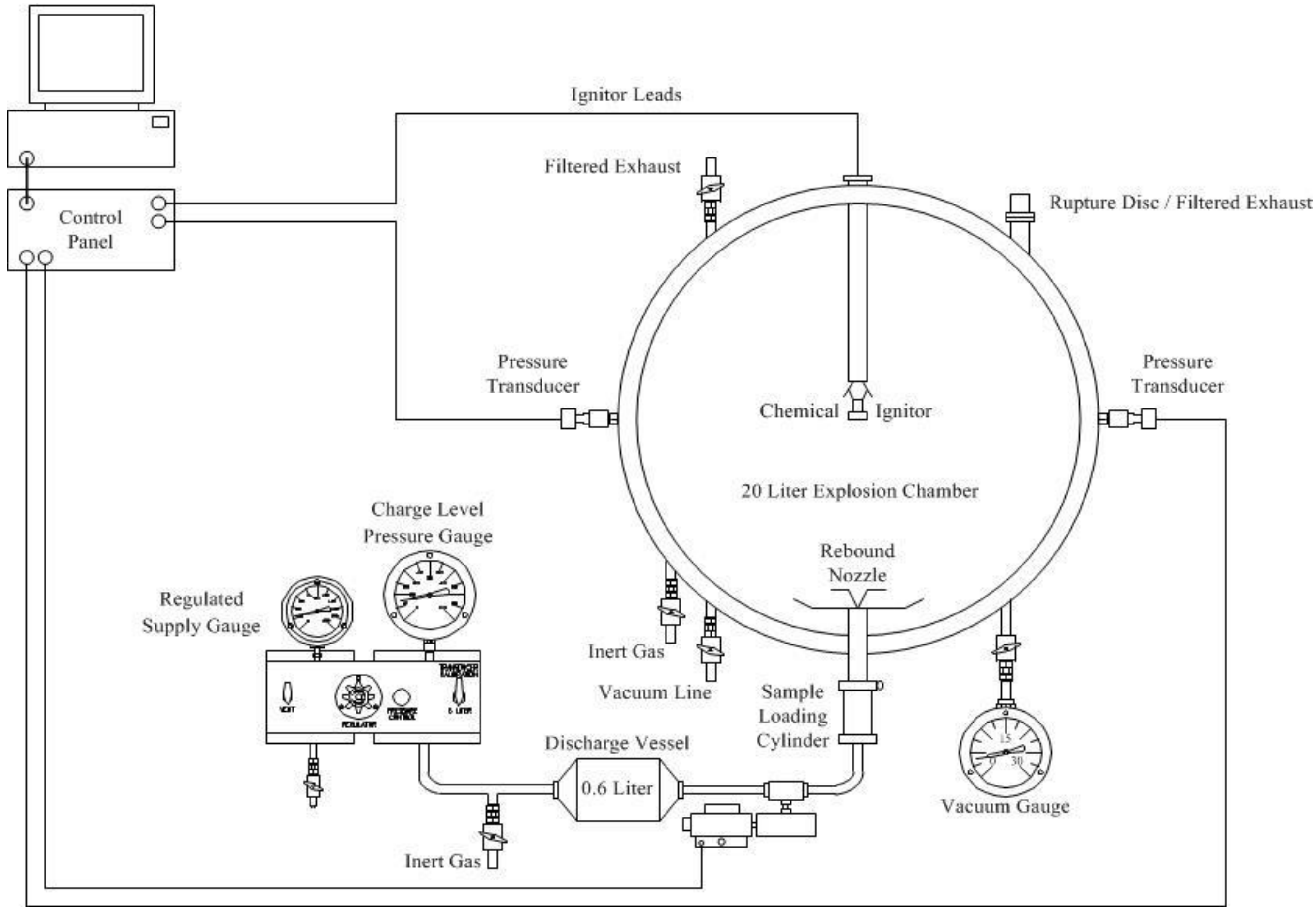

Figure 2: 20 Liter Apparatus

The table below shows the pressure settings used in the 0.6 liter discharge vessel and the 20 liter explosion chamber to obtain the desired oxygen concentration in the final dust cloud. The example shows the calculation for an initial pressure of 5.50 psia in the 20 liter explosion chamber.

Table 1: Partial Pressure Calculation Example

O_2 Concentration	0.6 Liter Vessel		20 Liter Vessel	
	Air (psig)	N_2 (psig)	Vacuum (psia)	N_2 To (psia)
21%	290	0	5.50	n/a
20%	290	15	5.24	5.50
19%	290	29	4.98	5.50
18%	290	44	4.71	5.50
17%	290	58	4.45	5.50
16%	290	73	4.19	5.50
15%	290	87	3.93	5.50
14%	290	102	3.67	5.50
13%	290	116	3.40	5.50
12%	290	131	3.14	5.50
11%	290	145	2.88	5.50
10%	130	290	2.62	5.50
9%	116	290	2.36	5.50

O_2 concentrations below require evacuating the 20 liter test vessel and backfilling it with N_2 a total of 3 times prior to filling.

O_2 Concentration	0.6 Liter Vessel		20 Liter Vessel	
	Air (psig)	N_2 (psig)	Vacuum (psia)	Air To (psia)
8%	101	290	3.40	5.50
7%	87	290	3.67	5.50
6%	72	290	3.93	5.50
5%	58	290	4.19	5.50
4%	43	290	4.45	5.50
3%	29	290	4.71	5.50
2%	14	290	4.98	5.50

O_2 concentrations of less than 2% require evacuating the 0.6 liter discharge vessel and backfilling it with N_2 a total of 3 times prior to filling.

O_2 Concentration	0.6 Liter Vessel		20 Liter Vessel	
	Air (psig)	N_2 (psig)	Vacuum (psia)	Air To (psia)
1%	15	290	5.24	5.50
0%	0	290	5.50	n/a

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