WHITE PAPER

The 1m³ Vessel for Determination of Explosion Severity - Why Use It?

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For many years the vast majority of dust explosion testing has been performed in the 20-liter spherical vessel. This equipment has been so well established as the workhorse of dust explosion laboratories around the world that it is easy to forget that there are times when it is necessary to go back to the gold standard for **dust explosion testing**: the 1m³ explosion vessel.

Early dust explosion testing was carried out in small-scale equipment, typically a cylindrical vessel with a volume of 1-liter (0.001m³), often designed based on experience with gas explosions. The most well-known and best established equipment was the “Hartmann apparatus” developed at the US Bureau of Mines (Dorsett, H.G., Jacobson, M., Nagy, J., and Williams, R.P. “Laboratory Equipment and Test Procedures for Evaluating Explosibility of Dusts”, R.I. 5624, U.S. Bureau of Mines, Washington, DC, 1960).

It was, however, soon recognized that all small-scale equipment (such as the Hartmann apparatus) suffered from a serious drawback: the results for explosion severity (maximum explosion pressure and maximum rate of pressure rise) could not be scaled to larger volumes. This of course also implies that the data measured at small scale do not represent what must be expected at full plant scale, a serious shortcoming in the applicability of the data. It also turned out that the data from small-scale equipment did not necessarily rank various materials in the same order of severity as **large scale testing** would. Finally, the low-energy ignition source (some 10s of Joules) used in small-scale equipment could fail to ignite some hard-to-ignite dusts, thus ranking them as “non-explosible” while in fact they could pose a dust explosion hazard. These insights led to the development of larger scale equipment, in particular a vessel with a volume of 1m³.

The 1m³ vessel was developed in Germany at the Bergbau-Versuchsstrecke (BVS) in Dordtmund-Derne under the leadership of Dr. Wolfgang Bartknecht. The 1m³ vessel combines a number of advances over the Hartmann apparatus and other similar

$1m^3$ Vessel for Explosion Severity Testing

small-scale equipment. Firstly, the large-scale volume avoids the excessive wall effects of small vessels (such as cooling of the combustion gases), so that the maximum pressure attained is close to the pressure expected based on the adiabatic flame temperature. Secondly, while the Hartmann apparatus method created a dust cloud with low levels of turbulence, the turbulence levels in the $1m^3$ vessel are high, better representing a worst-case situation to be expected in real life plant incident scenarios. This work was supported by research using actual plant equipment, including, for example, comparing the explosion effects in a running mill (particle size reduction equipment) and the same mill using the $1m^3$ dust injection system. And the $1m^3$ vessel uses a 10 kJ chemical igniter instead of a low-energy spark or electrical arc which might have an energy of some 10s of Joules.

Over time, the $1m^3$ vessel became more widely accepted, and Round-Robin (comparative) testing showed that consistent results could be obtained between test institutes. However, there was reluctance in the market to move to the $1m^3$ vessel by those who were unwilling or unable to accept the consequences of the change: no more quick bench-scale testing using small amounts of sample. Nevertheless, the advantages of the $1m^3$ vessel were so well established by the early 1980's that an international working group could prepare an international standard based on the $1m^3$ vessel, which was published in 1985 as ISO 6184-1: "Explosion protection systems - Part 1: Determination of explosion indices of combustible dusts in air". Later, when the European Union introduced the ATEX Directives and needed to standardize, among others, test methods for explosion characteristics, once again the $1m^3$ vessel was chosen as the basis for the EN 14034 series of standards published in 2004-2006.

Even though the advantages of the $1m^3$ vessel were clear, there was a need for a smaller-scale alternative test vessel, so that tests could be conducted more quickly and require less sample material, which is often a challenge, particularly when new products are being developed. The result was a spherical vessel with a volume of 20 liters, sometimes called the "Siwek vessel" after Richard Siwek who developed the vessel at the Ciba-Geigy explosion safety department run by Dr. Bartknecht. The 20-liter sphere apparatus was developed while maintaining the main characteristics of the $1m^3$ vessel: the dust dispersion mechanism and the high-energy ignition source. Nevertheless, in order to obtain data commensurate with the $1m^3$ vessel, certain adjustments were required, such as applying a correction factor to the maximum **explosion pressure**.

However, the high-energy ignition source (10 kJ) used in the 20-liter sphere apparatus can pose some challenges. This is because just firing the igniter in an empty 20-liter vessel already creates a significant temperature and pressure increase, changing the initial ignition conditions compared to the normal ambient conditions assumed for the testing. Thus, it may be hard to distinguish a slow (low severity) dust explosion from the "empty vessel" signal. Even more challenging, the high temperature can cause ignition of dust clouds that would not normally be ignitable under normal ambient conditions, so-called "false positives". Rarely a test in the 20-liter sphere will not yield the "S-curve" type of pressure-time history one expects from a dust explosion, such as when a product violently decomposes at the temperature and pressure conditions in the sphere.

In spite of these critical comments, experience has shown that the 20-liter sphere allows the generation of reliable explosion severity data, as well as MEC (minimum explosive concentration) and LOC (limiting oxygen concentration) data for the vast majority of materials that need testing.

The above brief discussion does clearly demonstrate that the $1m^3$ vessel is not just of historical or academic interest and that there remains a real need for explosion severity testing using $1m^3$ vessels. After all, the $1m^3$ vessel is the original vessel that has been shown to adequately reproduce dust explosions at full scale and has been providing the data against which other explosion test vessels can be calibrated, as prescribed in the relevant standards mentioned above. The $1m^3$ vessel therefore remains the "gold standard" in dust explosion testing - that means any test result that is "suspect" in the 20-liter sphere, such as a suspected "false positive", should be verified in the $1m^3$ vessel.

The 1m³ vessel has another advantage: because of its scale one can often design custom testing that would not be possible in a smaller vessel. This can range from using other, “real life” ignition sources to different ways of dispersing the dust, for example when the product cannot reliably and reproducibly be dispersed using the standard mechanism, and any other variation that may be necessary for a particular project.

Finally, it should be noted that the 1m³ vessel is also suitable for testing gas explosions and any other fuel-air mixtures, as per ISO 6184-2 (combustible gases in air) and ISO 6184-3 (fuel/air mixtures other than dust/air and gas/air mixtures) standards.

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Pieter Zeeuwen, M. Sc., is a Senior Process Safety Specialist at DEKRA Process Safety. He has more than 30 years experience in the gas and dust explosion fields, including materials testing, small and large scale explosion research, and consultancy for industry and government agencies in number of countries. His areas of expertise include gas and dust explosion hazard assessment, gas and dust explosion prevention and protection, electrostatic hazard assessment, hazardous area classification, and gas cloud explosions as well as incident investigations. Over the years, Mr. Zeeuwen has served on many working groups including various Standards committees, both nationally and internationally, e.g. most recently CEN (European Standards Committee) working groups on explosion protection methods and on test methods. He regularly lectures on various aspects of explosion safety and acts as seminar chairman and course director. Mr. Zeeuwen has published numerous articles in scientific journals and presented many papers at international conferences.

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