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Dust Explosion Venting: EN Standard 14491 vs. VDI-Guideline 3673

Richard Siwek; Kees van Wingerden,
FireEx Consultant GmbH; Incom Explosionsschutz AG,
CH-4304 Giebenach, Switzerland; CH-4603 Olten, Switzerland

The VDI 3673 Part 1 : 2002 "pressure venting of dust explosions," as well as the European Standard EN 14491 : 2002 "dust explosion venting systems", give both information regarding the calculation of the influence of vent ducts upon the pressure increase in the vented vessel, which are installed downstream the pressure venting device.
In the two standards, different numerical value equations for this calculation are indicated.
The paper provides a detailed investigation and compared the two methods to each other. It shows that an agreement between the two different numerical value equations exists only in several vessel volumes. As a conclusion of this investigation, a new design guideline for the estimation of the influence of vent ducts upon the pressure increase in the vented vessel is presented which will serve as a new base for the working groups for revising the corresponding standard guideline respectively.

1. Introduction

If a vent duct is attached downstream of the venting device, then after activation of the venting device the vent duct may be filled with an explosive mixture before the flames leave the vented vessel. This results in a secondary explosion in the vent duct, which will hinder the venting process. Therefore, the maximum reduced explosion overpressure inside the vessel will increase with increasing length of the vent duct. The pressure effect depends upon the expected maximum reduced explosion overpressure while using a venting device but without vent duct and upon type of the fuel.
The influence of vent duct upon the pressure increase in protected vessels is most pronounced when the flame propagation from the secondary explosion in the vent duct reaches the velocity of sound. This length of pipe L_S were the speed of sound is reached respectively where the ratio $(L/D)_S$ is reached can be estimated
<u>according to VDI 3673-2002:</u>

$$L_S = 4.564 \cdot P_{red,max}^{-0.37} \quad \text{in m} \tag{1}$$

<u>according to EN 14491-2002:</u>

$$(L/D)_S = 4.564 \cdot P_{red,max}^{-0.37} \quad \text{in m} \tag{2}$$

Where

L_S length of vent duct were the speed of sound is reached in m
$(L/D)_S$ length diameter ratio of vent duct were the speed of sound is reached
$P_{red,max}$ maximum explosion overpressure in the vented vessel without vent duct in bar

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Vent ducts with a length of $L > L_S$ or $L > L_S/D$ have no additional effect upon the pressure increase. Therefore, L_S will be the maximum length or L_S/D the maximum length to diameter ratio that has to be considered. The above-mentioned equations (1) and (2) are not valid for metal dusts.
Experimental studies have proven that the influence of vent duct with longitudinal arrangement - located on the roof - decreases markedly with increased length diameter ratio of the vessel. The increase of the maximum explosion overpressure is at its maximum if the vessel length diameter ration is 1. The maximum reduced explosion overpressure $P'_{red,max}$ caused by the downstream duct can be calculated for vessels having a length diameter ration of 1 with the following equation:
According to VDI 3673-2002:

$$P'_{red,max} = P_{red,max} \cdot (1 + 17.3 \cdot L \cdot (A \cdot V^{-0.753})^{1.6}) \quad \text{in bar} \tag{3}$$

According to EN 14491-2002:

$$P'_{red,max} = P_{red,max} \cdot (1 + 17.3 \cdot L/D \cdot (A \cdot V^{-0.753})^{1.6}) \quad \text{in bar} \tag{4}$$

Where
$P'_{red,max}$ maximum explosion overpressure in the vented vessel with vent duct in bar
$P_{red,max}$ maximum explosion overpressure in the vented vessel without vent duct in bar
L length of vent duct in m
L/D length diameter ratio of vent duct
A geometric vent area in m^2
V volume of protected vessel in m^3

2. Comparison Of The Calculation methods

2.1 Maximum vent duct length L_S

For fife different vessel volume V, two vent areas A, three maximum explosion overpressure P_{max}, four maximum explosion constant K_{max} at constant activation overpressure of the venting device of P_{stat} = 0.1 bar, the calculated maximum length of the vent duct L_S according to the VDI 3673 equation (1) and EN 14491 equation (2) are plotted in Figure 1.
Figure 1 compares the relation between the vent area A and the maximum vent duct length L_S for both equations (1) and (2). In the area of about 1 m² both equations are giving similar results.
Figure 2 shows the influence of the vessel volume V upon the maximum vent duct length L_S calculated from the equation (1) and (2). For better presentation, all values calculated for L_S from equation (2) were averaged for each vessel volume and vent area.

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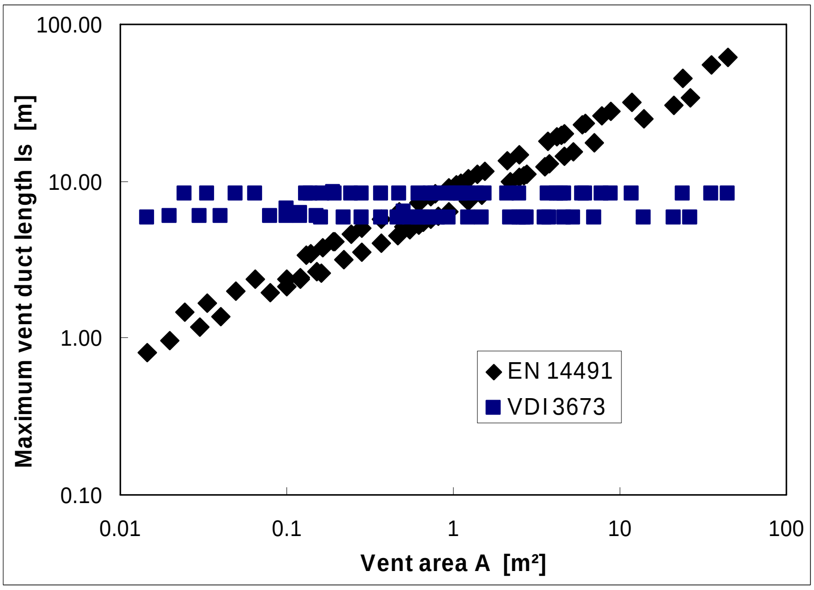

Figure 1. *Influence of the vent area A upon the maximum vent duct length l_S calculated from the equation (1) and (2).*

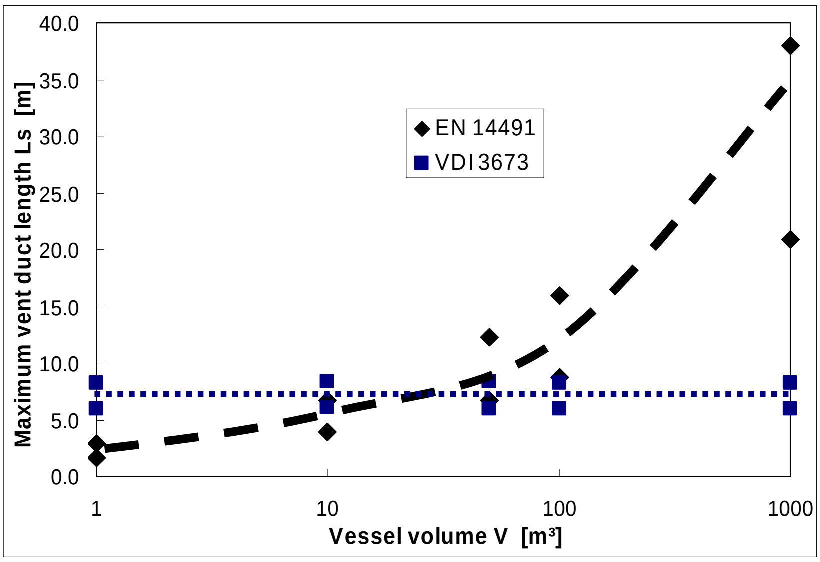

Figure 2. *Influence of the vessel volume V upon the maximum vent duct length l_S calculated from the equation (1) and (2).*

Figure 2 shows also clearly that in the range of vessel volume of V = 30 m³ both equations are giving similar results.
Figures 1 and 2 shows clearly that both equations have their limits of application. For smaller vessel volumes – and therefore for smaller vent areas the equation (1) seems to give more realistic values for L_S, whereas for larger vessel volumes – and therefore for larger vent areas the equation (2) seems to give more realistic values of the L_S.

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Above statement is feasible, because the experimental investigations regarding the influence of vent ducts one the maximum reduced explosion overpressure $P_{red,max}$ in vented vessel are mainly based for equation (1) in volumes of 1 and 2.4-m³ Siwek (2002) and for equation (4) in a volume of 18.5-m³, Lunn, G. A (1988) and Lunn, G., Crowhurst, D., and Hey, M. (1988).


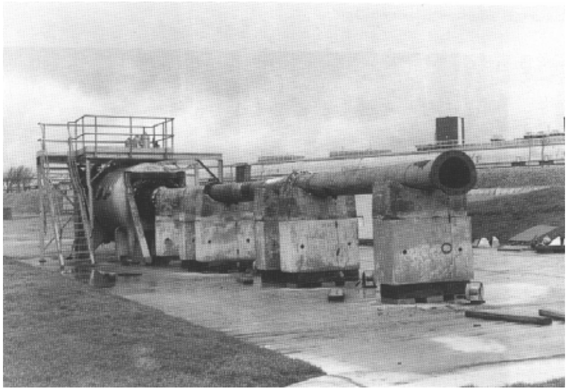

Figure 3. 2.4-m³-vessel (left) and 18.5-m³-vessel for dust explosion venting test with and without vent pipe.

Figures 1 and 2 shows clearly that both equations have their limit of application. For smaller vessel volumes – and therefore for smaller vent areas the equation (1) seems to give more realistic values for L_S, whereas for larger vessel volumes – and therefore for larger vent areas the equation (2) seems to give more realistic values of the L_S.

2.2 Influence of different vent duct length L

For four different vessel volume (V=1, 10, 30 and 1000-m³), three vent areas, three maximum reduced explosion overpressure and a constant activation overpressure of the venting device of P_{stat} = 0.1 bar, the maximum reduced explosion overpressure $P'_{red,max}$ are calculated for vent duct of three different length (L = 1, 3 and 5-m) according to VDI 3673 equation (3) and EN 14491 equation (4) and plotted in Figure 4 for a K_{max} = 200 $m \cdot bar \cdot s^{-1}$ and in Figure 5 for a K_{max} = 300 $m \cdot bar \cdot s^{-1}$.
For smaller vessel volumes (1 to 10-m³) the equation (3) seems to give more realistic values for $P'_{red,max}$, whereas for larger vessel volumes (V >30-m³) equation (4) seems to give more realistic values of the $P'_{red,max}$.
For the vessel volume of 10-m³, both equations (3) and (4) give in order of magnitude the same $P'_{red,max}$ value. Again, the above statement is feasible, because the experimental investigations regarding the influence of vent ducts one the maximum reduced explosion overpressure $P_{red,max}$ in vented vessel are mainly based for equation (3) in volumes of 1 and 2.4-m³, Siwek (2002) and for equation (4) in a volume of 18.5-m³, Lunn, G. A (1988) and Lunn, G., Crowhurst, D., and Hey, M. (1988).

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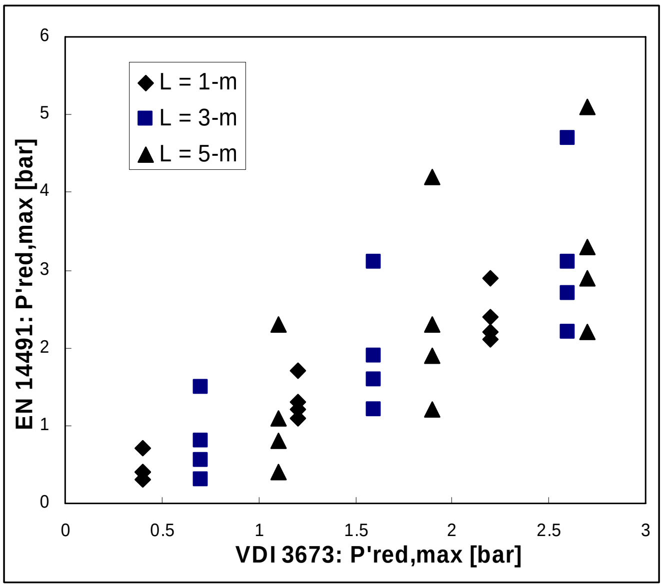

Figure 4. *Influence of the different equations upon the maximum reduced explosion overpressure with different length of vent ducts (P_{max} = 9bar, K_{max} = 200m·bar·s^{-1}).*

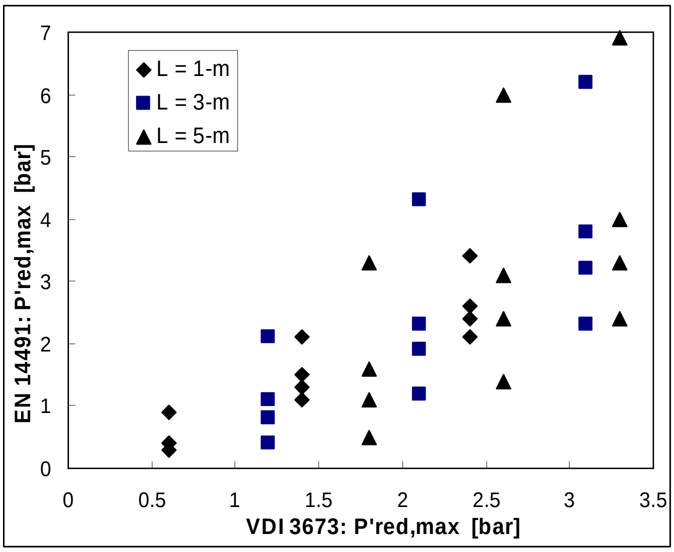

Figure 5. *Influence of the different equations upon the maximum reduced explosion overpressure with different length of vent ducts (P_{max} = 9bar, K_{max} = 300m·bar·s^{-1}).*

2.3 Conclusion

The findings in 2.1 to 2.2 shows clearly that the equations (1) to (4) used for calculation of the maximum reduced explosion overpressure $P'_{red,max}$ for different length of vent ducts and for calculation the length of pipe L_S , that an agreement between the different numerical value equations exists only in vessel volumes in the range of 30-m^3.

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The VDI 3673 equations (1) and (3) give more realistic values for volume up to approximately 30-m^3 whereas the EN 14491 equations (2) and (4) give more realistic values for volume larger than approximately 30-m^3.
Additional venting tests are plant in larger volumes such as 25-m^3 and 60-m^3 to support the above-mentioned findings.
As a conclusion of this investigation, a base for a new design guideline for the estimation of the influence of vent ducts upon the pressure increase in the vented vessel is presented. It will serve as a new base for the working groups for revising the corresponding standard guideline respectively.

3. References

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