VENT SIZING FOR FIRE

CONSIDERATIONS FOR

HEAT FLUX VARIATIONS DUE TO

FUEL COMPOSITION

Developed by the

DIERS USERS GROUP

ERS DESIGN FOR FIRE COMMITTEE

May 15, 2000

VENT SIZING FOR FIRE CONSIDERATIONS FOR HEAT FLUX VARIATIONS DUE TO FUEL COMPOSITION

Background

The methods for calculating heat flux to a vessel exposed to fire are well documented. API RP 520, 521, Standard 2000 and NFPA 30 are basic industry guidelines providing correlations to calculate this heat flux. Other guidelines are available for less general cases. Given the heat flux, a relieving rate can be calculated to prevent vessel damage due to over pressure. Considering height and geometry variables, the heat flux is calculated based on exposed vessel wall area which is wetted by internal liquids. Some add a contribution due to heat flux through unwetted surfaces.

These API and NFPA heat flux correlations are based on tests conducted using petroleum refinery stocks as the fuel. Is it possible that the heat flux to a vessel exposed to a significantly different fuel fire is higher or lower than these correlations predict?

Issue

These NFPA and API heat flux correlations were based on test data where the fluid burning outside the exposed vessel was a petroleum-based hydrocarbon mix such as gasoline or kerosene. It is well known that other fluids have substantially different heats of combustion. In fact, there is already some code guidance on this subject. NFPA 30, 2-3.6.7 permits an additional environmental factor of 0.5 for ethanol systems. This document will expand on that point for other fluids and provide a more detailed, quantitative technical basis for calculating a burning rate factor. This document will focus on heat flux reductions based on fuel compositions. If a particular fuel can cause significantly higher heat rates than typical hydrocarbon fuels, then this aspect should be investigated separately.

Contents

Guidelines

1. All of these guidelines apply to vent sizing for the external fire case. As always, there may be additional over pressure scenarios that may apply. If one of the alternate scenarios requires a larger vent than the fire case, then the larger vent should be installed. If this is done, the fire case and its relieving rate should still be documented.

2. Refer to the documents, "Vent Sizing for Fire Considerations for Special Equipment and Piping" and "Vent Sizing for Fire Considerations for Jacketed Vessels" for additional guidelines that may apply to the case of small or unusually shaped equipment, exchangers and vessel jackets exposed to fire.

3. As mentioned above, NFPA 30, 2-3.6.7 permits a reduction of the environmental factor (F) by 0.5 when the burning fluid is ethanol. The minimum acceptable resulting value for F is 0.15.

4. NFPA 30 permits this heat flux reduction for other "liquids whose heats of combustion and rates of burning are equal to or less than those of ethyl alcohol (ethanol)".

5. NFPA provides no guidance on how to determine a fluid's heat of combustion or rate of burning. The guidelines that follow provide one means to quantify a fluid's burning rate and heat of combustion.

6. The burning fluid that provides a basis for the API and NFPA heat flux equations is not clear. Many of the tests done to determine heat flux data used gasoline or kerosene as the burning fuel.

7. Calculations were done comparing ethanol to hexane and to nonane. Using the proposed formula (below), the comparison to nonane was more conservative in that it yielded a higher reduction coefficient. Consequently, this paper will recommend a method that compares a burning fluid's characteristic to nonane.

8. Therefore, this paper proposes calculating and using a burning rate factor based on a predicted spilled liquid's burning characteristics. This factor is to be multiplied by the NFPA or API environmental factor before calculating an overall heat input rate to a vessel exposed to an external fire. In no case shall the resulting overall heat flux reduction factor be lower than 0.15 under NFPA methods or 0.026 under API methods.
9. The burning rate factor is calculated using the following formula:

$$BRF = \frac{\dfrac{2\ HC^{2}}{HV + CP\ (\ T_{BP} - T_{a}\ )}}{\dfrac{19054^{2}}{124.5 + 0.821\ (\ 763 - T_{a}\ )}}$$

Subject to the limitation of:

$$BRF \leq 1$$

where:

BRF	=	Burning Rate Factor, dimensionless
2	=	Conservatism factor
HC	=	Liquid heat of combustion, BTU/lb (lower heating value)
HV	=	Liquid heat of vaporization at T_{BP}, BTU/lb
CP	=	Liquid heat capacity at T_{BP}, BTU/lb-°R
T_{BP}	=	atmospheric pressure boiling point, °R
T_a	=	Ambient or ground temperature, °R
19054	=	Nonane heat of combustion, BTU/lb
124.5	=	Nonane heat of vaporization at T_{BP}, BTU/lb
0.821	=	Nonane liquid heat capacity at T_{BP}, BTU/lb-°R
763	=	Nonane normal boiling point, °R

10. If there is the potential for more than one fluid to spill or leak and begin burning near the subject vessel, for design, use the fluid that results in the higher burning rate factor.

11. Example: ethanol gets the following BRF:

HC	=	Liquid heat of combustion, 11528 BTU/lb (lower heating value)
HV	=	Liquid heat of vaporization at T_{BP}, 367.7 BTU/lb
CP	=	Liquid heat capacity at T_{BP}, 0.717 BTU/lb-°R
T_{BP}	=	One atmosphere boiling point, 632.5 °R
T_a	=	Assumed ambient or ground temperature, 530 °R

insert these values into the BRF formula:

$$BRF = \frac{\dfrac{2\ (\ 11528^{\ 2}\ )}{367.7 + 0.717\ (\ 632.5 - 530\ )}}{\dfrac{19054^{\ 2}}{124.5 + 0.821\ (\ 763 - 530\ )}}$$

BRF = 0.52 (NFPA 30 recommends 0.5 for ethanol)

12. Overall environmental factor examples (with the above BRF of 0.52)

A. Uninsulated tank; F = 1
Overall F = 0.52*1 = 0.52

B. NFPA valid insulation; F = 0.3
Overall F = 0.52*0.3 = 0.156

C. NFPA valid insulation, water spray <u>and</u> drainage; F = 0.15
Overall F = 0.52*0.15 = 0.078 -> use minimum value of 0.15

D. API valid insulation with thickness and conductivity good for F = 0.15
Overall F = 0.52*0.15 = 0.078

E. API valid insulation with thickness and conductivity good for F = 0.03
Overall F = 0.52*0.03 = 0.0156 -> use minimum value of 0.026

Additional References.

1. American Petroleum Institute "Sizing, Selection and Installation of Pressure-Relieving Devices in Refineries", API Recommended Practice 520, Part 1, Sixth Edition, 1993.

2. American Petroleum Institute "Guide for Pressure-Relieving and Depressuring Systems", API

Recommended Practice 521 Fourth Edition, 1997.

3. American Petroleum Institute "Venting Atmospheric and Low-Pressure Storage Tanks", API Standard 2000 Fourth Edition, January 1992.

4. National Fire Protection Association, "ANSI/NFPA 30, Flammable and Combustible Liquids Code", 1996 Edition.

5. H.G. Fisher, H.S. Forrest, S.S. Grossel, J.E. Huff, A.R. Muller, J.A. Noronha, D.A. Shaw, B.J. Tilley, "Emergency Relief System Design Using DIERS Technology (The Design Institute for Emergency Relief Systems (DIERS) Project Manual), The Design Institute for Emergency Relief Systems of the American Institute of Chemical Engineers, 1992.

Acknowledgements

The following individuals made significant contributions to the development of this document. Their efforts are appreciated.

Fred P. Nichols	Imperial Chemical Industries
John J. Hauser	PROSAF Inc.
John Stipanovich	Aristech
Stan Grossel	Process Safety & Design