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What is the mitigation, if relieving temperature is greater than vessel wall temperature?

Sampath Kumar R
Upstream Process Engineer at Technip

Dear Friends,

Greetings of the Day!!!

I have one clarification. Pressure build up (as a result of fire scenario) in a vessel contains two phase (Liquid + Gas), will be due to both gas expansion and liquid vaporization.
However, API-521 indicates that either the vapor thermal-expansion relief load or the boiling-liquid vaporization relief load, but not both, should be used.

While calculating the relieving temperatures for gas (using the API guidelines) or liquid (from HYSYS), often the relieving temperature (mainly gas relieving temperature) will be above the vessel wall temperature.

My questions are follows:

1.If the relieving temperature of the gas is higher than the vessel wall temperature (Tw), then relieving rate due to gas expansion will not be calculated as the formulae does not allow this:

Relief Load due to expansion =0.1406 (M .p1)^0.5 x A'(Tw-T1)^1.25 / (T1^1.1506)

Could you please clarify that is there any alternative method to find out the relieving rate due to gas expansion? Without knowing the relieving rate due to gas expansion, we cannot conclude that liquid vaporization will be the governing.

2. Can we proceed with vessel design temperature (which will be less than vessel wall temperature) as relieving temperature in such cases?

Thanks in advance for your time.

Kind Regards

Sampath Kumar R

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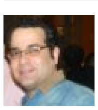

Mojtaba

Mojtaba Habibi
Process Engineer at Wood Group
Top Contributor

Dear Sampath Kumar R,

For your first question I have faced with similar problem at some of the previous projects. I propose you to use HYSYS dynamic depressuring utility to obtain the relief rate.

For your second question this is true that during fire case the vessel wall temperature may reach very high temperature values beyond the vessel design temperature but we are speaking about a rare case. So for design temperature we do not need to consider this case. The only case I have

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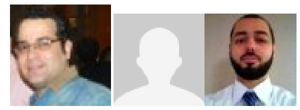

Mojtaba Habibi
Process Engineer at Wood Group
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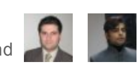

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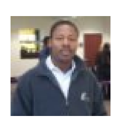

Oluseyi Ogunrinola commented on a discussion in Chemwork.

salman haider Guide on LPG loading pump installation in PIT.....? Can LPG loading pump(centrifugal pump) be installed in pit.. what code and practice should be followed in is regard. Installing LPG loading pump in pit meets license seen that fire case temperature is included by some companies for setting the design temperature is flare network.

Best,
Mojtaba

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Mohammadreza

Mohammadreza Ebrahimi
Senior Process Eng. at Nargan Engineers & Constructors

Dear Sampath

Based on my experiences for such cases, Vessel will be fire proofed and you can consider vessel design temperature as relief temperature for calculation of relief rate.

Best Regards
Mohammad reza

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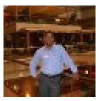

ANJARIA

ANJARIA HITESHKUMAR M.
LEAD TECHNICIAN at ExxonMobil

so does it mean that fire proofing is one of the consideration to safeguard the vessel for fire case over-temperature?pl. brief some more about fire proofing.thanks.

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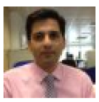

Saeid Rahimi Mofrad
Senior Specialty Process Engineer at Fluor

API-521 defines F' factor as:

F' = 0.1406 *(Tw-T1)^1.25/(T1^0.6506)/(C * Kd)

It also states that when F' is less than 0.01, then use a recommended minimum value of F=0.01. You can read more about background of this relation on
http://www.chemwork.org/PDF/board/The%20Basis%20of%20API%20Corrolation%20for%20Fire%20Relief%20of%20Unwetted%20Vessels.pdf

In your case, F' is less than 0.01 (it is actually less than zero! because Tw < = T1), so same recommendation can be followed. This means that relief rate can be calculated using below equation:

W = F'*A'*C*Kd*Kb*Kc*SQRT(P1*M/(T*Z)) where F'=0.01

This formula is derived if API-521, Jan 2007, equation (8), A = F'*A'/ SQRT (P1) is replaced in orifice area calculation from API-520, A = W* SQRT (T*Z/MW) / (C*Kd*Kb*Kc) to calculate W.

for definitions of abbreviations, refer to API-520 or 521.

By the way, I don't think using HYSYS depressuring tool or design temperature is right approach (which would be a long discussion)...

Delete • March 25, 2012

ANJARIA HITESHKUMAR M., Ali H. Gorji like this

S M

S M Kumar
Process Design Consultant

Dear Sampath: I fully endorse what Saeid Rahimi has said. Use Fmin value and move on. Fire-proofing or using design temp are not the right solutions. The situation you describe happens in vessels where design pressure is far higher than operating pressure. This results in high fluid temperature based on T1/T2 = P-relief/P-operating ratio. I have seen some engineers setting the PSV at a lower pressure than design, just to get T1, 100C below Tw. This may result in the fire case PSV becoming full capacity PSV if the upstream PSV is set at a higher pressure.

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ANJARIA HITESHKUMAR M. likes this

Sampath

Sampath Kumar R
Upstream Process Engineer at Technip

Dear SMK Sir / Saied,
We will arrive at flow rate by using F' = 0.01 . However, in this process, we are allowing relieving temp going beyond vessel wall temp. Can we allow relieving temp goes higher
than vessel wall temp?

requirements..?
3h ago

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4h ago

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I am facing exactly the same problem in one of my present projects. Due to wide difference between design and operating pressure, the relieving temperature had gone beyond vessel wall temperature. To limit the relieving temperature, I have reduced the set pressure such the relieving temp is within vessel wall temp. Is it a right approach or I need to go for F'=0.01 and proceed further irrespective of higher relieving temperature?

Kind Regards

Sampath Kumar R

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ANJARIA HITESHKUMAR M. likes this

S M

S M Kumar

Process Design Consultant

Dear Sampath: Please see my separate response why this a paper exercise. Go ahead with F min and T1 calculated for sizing PSV. Tell the PSV supplier via a note in your PSV datasheet to select the PSV flange rating based on design temp and use T1 only for sizing purposes. Otherwise at T1, even a 1500# flange rating may not be OK and it will be ridiculous to have a 1500# rated PSV on a 300/600# vessel.

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S M

S M Kumar

Process Design Consultant

I get a number of queries via direct mail. I am going to post the queries (without identifying the originator) and my responses here. This is to (1) to benefit other forum users and (2) to get multiple inputs and corrections from others on my comments - like the gas vs oil field query I responded wrongly. Unless someone wants to send me a confidential drawing/ document, I prefer queries via this forum. At times I am busy in Hazop days together and feel bad when I am unable to respond.

First one: 1. What is the basis for 100C temperature difference? 2. What do you mean by "This may result in the fire case PSV becoming full capacity PSV if the upstream PSV is set at a higher pressure. "

My response: 1. 100C. No basis. Individual preference - see Sampath talking about his preferred pratice above -, to keep fluid temperature below maximum metal wall temperature given in API. In fact, the fire case PSV sizing for a gas filled vessel is a paper exercise. In a vessel under fire, without a BDV, as the metal wall temperature increases, leading to internal pressure rise over time; metal's ability to hold pressure (yield strength) will fall. The vessel will fail when internal stress exceeds its ability to with stand internal pressure. So the vessel will rupture at a much lower pressure before the PSV pops or opens. [Example: Temperature Vs Yield stress at 400/800/1100 deg F = 100/80/36 units. That is a vessel that can withstand 100 psig will fail at 36 psig when the wall reaches 1100 deg F], before its PSV pops at 100 psig.

2. If the upstream PSV is set at higher pressure, then the lower set fire case PSV will open first on a blocked outlet scenario, that is downstream blocked. Then this PSV has to be rated for full flow. If upstream, and downstream PSVs are set at the same pressure, then the upstream will open first (due to pressure drop in the in between piping) and the upstream PSV will be sized for full flow and downstream PSV will be small sized for fire case!

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Amarnath

Amarnath S

Senior Process Engineer

Sampath,
your query is valid, as you said API considers only liq vap or gas exp. I referred to shell guideline also. Shell says the same thing.

Answer to your first query is check whetehr two phase is within fire zone or not. If so, comparitively liquid wetted area is more than the gas wetted area. in that case you can consider only the liq vap.

Answer to your second query is
you can calculate the releiving temperature and properties at releiving condition by multiple component flashing in hysys, where the vapour temp difference between two consecutive flashing are less than 2 deg c or almost equal. Even Shell says the same thing. You can refer to shell DEP

Hope it clarifies

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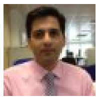

Saeid Rahimi Mofrad

Senior Specialty Process Engineer at Fluor

Sampath, in reality gas expansion and liquid vaporization occur at the same time and the relief rate at each moment is summation of both of them. However, API statement on using maximum of gas expansion or liquid vaporization case for relief valve sizing is very valid assumption, I think. Recently, I made some dynamic models (which I will share at the earliest on Chemwork) to study the behavior of different systems (containing sub cooled/saturated liquid - one/two liquid phases) during fire. I realized that due to number of conservative assumptions made in derivation of gas expansion formula and highly conservative approach we normally use for liquid vaporization, sizing relief valve for maximum of them is quite sufficient.

About question “Can we allow relieving temperature to go higher than vessel wall temperature?“

First of all, what API has specified as wall temperature (1100 deg F or 530°C) is only for the purpose of calculation. In reality, there is a high possibility of overheating vessel wall to a temperature beyond this limit since flame temperature is around 1500-2000°F.

We don’t design vessel for fire temperature because it is believed that automatic fire fighting system, fire team action, and depressuring will prevent vessel from reaching very high temperatures. Furthermore, depressuring will reduce the pressure of system so that it can withstand very high temperatures (beyond its design temperature or even wall temperature).

Delete • March 28, 2012

Sampath

Sampath Kumar R

Upstream Process Engineer at Technip

Dear Members,

Thanks to all for your contributions. Special thanks to Mr.SMK sir & Mr.Saied.

Based on the responses, I would like to conclude the discussion by saying the following statement:

If the relieving temperature is greater than the vessel wall temperature, we can consider F'=0.01 and proceed further. There is no need of reducing the set pressure.

Kind Regards

Sampath Kumar R

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Rohit

Rohit Mistry

Dy. Chief Engineer (Process) at Aker Solutions

Interesting discussion. I wish to add following points/ queries to this discussion and request members views:

Regarding Mr. Kumar's response to query no. 2, in my opinion, if downstream fire case PSV is set at lower pressure then upstream PSV, it need not be sized for blocked outlet (assuming we are only reducing fire case PSV set pressure and not vessel design pressure). During blocked outlet scenario, the fire case PSV will pop first and relieve fluid upto its rated capacity. If required relieving rate for blocked discharge case is higher than rate capacity of fire case PSV, it will lead to increase in system pressure and eventually get relieved from upstream PSV sized for blocked discharge flow.

Regarding automatic depressurization facility to prevent vessel failure during fire due to high temp., I have following queries:
1. I understand it is generally provided for systems designed for 17 barg pressure and above. Could somebody explain the reasoning behind 17 barg pressure and why it is generally not provided for system designed for pressure lower than 17 barg.
2. What are the other means for protecting vessel failure due to fire exposure, if its design pressure is lower than 17 barg. Can an automatically operated water sprinkler/ deluge ring be considered as an alternative to depressurization facility for such vessels?
3. Also if a particular vessel is provided with automatic depressurization facility on fire detection, do we specify its PSV for fire case relief?
4. Can adequately sloping floor (to prevent hydrocarbon accumulation) and provision of fire fighting facilities eliminate above requirements?

Regards,

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S M

S M Kumar

Process Design Consultant

Valid point Rohit. I agree that if downstream vessel design pressure is the same as upstream, then there is no need to size its PSV for blocked discharge.

Your queries:
1. I have not seen the 17 barg requirement before. The lower design pressure vessels have thinner walls and they require more protection. One of the leading oil companies design engg pratice clearlyt spells its out
2. No
3.Yes. You still do to meet ASME requirements for vessels. Relief valves are mechanical protection with lower failure rate and are the ultimate protection
4. It is good to do so; but does not eliminate it. Again, as I mentioned in another post, extent to which depressurisation is implemented is not uniform across upstream-downstream industries.

Like • Reply privately • Delete • April 16, 2012

Rohit

Rohit Mistry

Dy. Chief Engineer (Process) at Aker Solutions

Thanks for the inputs Mr. Kumar. Below are the quotes in some of the most popular codes/ guidelines based on which I had raised above queries:

API 521-2007 Pg 56
'Emergency depressuring for the fire scenario should be considered for large equipment operating at a gauge pressure of 1700 kPa (approx. 250 psi) or higher.'

Shell DEP 80.45.10.11 Jan 2010 Pg 29
'Overpressure protection is not required for pressure vessels in vapour service if fire is the only overpressure scenario. Such vessels SHALL [PS] be protected by making them accessible to fire fighting or by providing them with water deluge, fire proofing or a
vapour depressuring system.
NOTE: It is superfluous to install a pressure relief device on vessels in vapour service that normally do not have a liquid inventory (e.g., gas filters, vapour phase reactors, compressor suction and discharge pulsation damper vessels) since vessel failure due to overtemperature is likely to occur with or without the pressure relief device.'

I agree with your comment regarding non-uniformity in implementation of depressurization across unstream-downstream industry.

Like (1) • Reply privately • Delete • April 17, 2012

ANJARIA HITESHKUMAR M. likes this

S M

S M Kumar

Process Design Consultant

Thanks Rohit (1) API 521 250 psig limit. Sorry, I have totally forgotten it after getting ingrained that the thin walls LP vessel need equal protection (2) DEP: This is the first time I am seeing this right and categorical statement. Thanks. It is a good and valid point. I am also saying the same thing about the utility of a fire case PSV. But I am under the impression that code stamped vessels - need a PSV! Pls chjeck with your project mechanical engineer

Like (1) • Reply privately • Delete • April 17, 2012

ANJARIA HITESHKUMAR M. likes this

Hooman

Hooman Tabaraei

Specialist Process Engineer (MIChemE, CEng)

Dear All, As you may know, in case of installing PSV at compressor suction side, relief temperature at gas expansion fire case will be calculated based on settle-out condition instead of operating pressure,i.e. Trelief/Tsettle-out = Prelief/Psettle-out, and secondly we can use BDV instead of PSV while gas expansion has become governing case, and relief temperature is above maximum allowable metal temperature. We utilized BDV instead of PSV in a project at similar situation to prevent promoting the material of vessel due to high relief temperature during the fire gas expansion.

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Mojtaba

Mojtaba Habibi

Process Engineer at Wood Group

Top Contributor

Dear Hooman,

Based on section 5.15.4 of API 521-2007 edition, BDV can be used as additional protection for the case under discussion (gas filled vassel). This is alse mentioned at API that:
"Since depressuring systems/procedures can fail, no credit for the depressuring system is recommended when pressure-relief devices are being sized for fire exposure."

What to do if BDV fails on demand during fire case while supposed to act as ultimate safegaurd against overpressure instead of PSV as described by you?

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Pedro

Pedro Marcano
Principal Consultant Process Engineer at Foster Wheeler

Dear All,

This is a general question regarding the comment done by Mr. S M Kumar (March 27th): I have seen some engineers setting the PSV at a lower pressure than design, just to get T1, 100C below Tw. This may result in the fire case PSV becoming full capacity PSV if the upstream PSV is set at a higher pressure.
What happens if you're in the desing phase and you calculate the orifice required at a set pressure lower than MAWP. Can this working?.
I don't understand the API-520 Part I statement that mentions that for diferents set pressures the relieving pressure is the same (table 4). somebody can help me with these two questions.
Thanks in advance for your support.

Pedro Marcano
Principal Process Engineer - Foster Wheeler UK.

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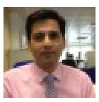

Saeid Rahimi Mofrad
Senior Specialty Process Engineer at Fluor

I believe the need and effectiveness of reducing the PSV set pressure for protecting a gas filled vessel against thermal decomposition and equipment failure at lower pressure than the design pressure was ruled out in the previous posts. To answer your question about API-520, table 4:

ASME VIII Div. 1 states that the pressure relief device which is used as protection against excessive pressure caused by exposure to fire or other sources of external heat, shall have a relieving capacity sufficient to prevent the pressure from rising more than 21% above the maximum allowable working pressure (MAWP) of the vessel when all pressure relief devices are blowing.

if we assume that MAWP (which is usually taken same as the design pressure for simplicity) is 100 psig, using 21% allowable over pressure, the vessel can be exposed to the maximum pressure of 121 psig, regardless of what the PSV set pressure is.

1) if you set the the PSV set pressure at the design pressure, PSV will open at set pressure, pass the flow and reaches full open position when system pressure increases to 121 psig.

2) if you set the PSV set pressure below the design pressure at 90 psig for instance, using 21% over-pressure, the orifice area to handle a fixed relief load will be larger. PSV will open at a lower pressure than design pressure, pass the required flow and will reach the full open position at 121% of set pressure (108.9 psig) which is lower than what Code allows.

Nevertheless, in this case you can take the advantage of code and specify higher over-pressure than 21% to reduce the PSV size. The allowable over pressure can be 31 psi (121 psig - 90 psig). The over-pressure in this case will be 134% of the set pressure but only 21% above the design pressure inline with code requirement.

This concept has been depicted in the Table-4 of API-520.

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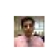
NOMAN ZAHEER
Sr. Process Design Engineer at Aker Solutions




Pedro

Pedro Marcano
Principal Consultant Process Engineer at Foster Wheeler

Dear Saeid,

Thank you very much for your answer. I will be sure that your comments are ed to the use of the existing valve in a new set point for the same vessel.

If we can sizing a new valve with a new set point for a vessel that have a design pressure higher that the set point, but using the sizing calculation at 121% of the new set pressure will have a PSV bigger than this one calculated at set point equal to design pressure.

With the new valve I don't see the reason to have 134% of the set pressure using the new valve sized.

I will appreciate your comment and clarifications.

Thanks again for your interest in my questions.

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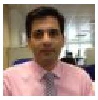

Saeid Rahimi Mofrad

Senior Specialty Process Engineer at Fluor

Dear Pedro,

The answer I have given above is general and applicable to both existing and new designs.
I suggest you to describe the case you are dealing with in detail in order to get the right answer.

Regards
Saeid

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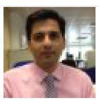

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