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Relief Flare Analysis using a Dynamic Simulation Model of your Plant

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There are various situations in which it is necessary to reevaluate the capacity of a site's existing flare system, but all of them seem to present only one solution when such capacity is reaching its limit: a capital project to increase it. Conventional engineering approach for calculating the reliefs from units to the flare systems is based on Steady State assumptions, SSB, while the relief load to the flare during an emergency scenario is basically a highly transient behavior. Therefore, the conventional approach tends to fail when providing accurate estimations of the relief load and safety becomes guaranteed by very conservative assumptions applying such methodology. The conclusion of the abovementioned facts is that industry often goes to a CAPEX solution because it applies a traditional methodology which requires a conservative approach to guarantee the safety of the system.

In 2007, API 521 already recommended the use of Dynamic Simulation because it improves the understanding of what happens during a relief and provides a more accurate analysis of the loads send to the flare system.

However, despite that API 521 also indicates that conventional methods for calculating relief loads are generally conservative and can lead to overly sized relief- and flare system design, sixteen years later, SSB methods are the widespread approach applied by engineering companies while dynamic simulation is only reserved for "special cases", Mo Abouelhassan (2022).

Why is dynamic simulation reserved only for special cases? There are two main reasons for that:

- SSB Conventional methods are believed to be conservative, oversizing the relief system, which is acceptable for the industry.
- Dynamic Simulation are thought to require a significant effort and therefore make difficult to manage deliverables on time and on budget.

Inprocess has been applying Dynamic Simulation to estimate the relief load since API 521 recommended it as an effective alternative to the steady state calculations, J.A. Feliu (2008). Along these sixteen years, more than 40 Dynamic Simulation Studies have been performed by

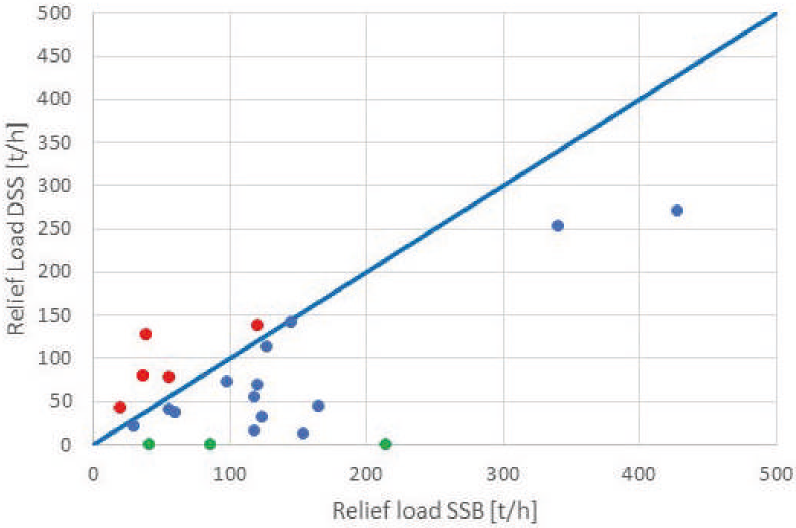

Figure 1. Relief Loaf from Conventional Steady State calculations versus Relief Load from Dynamic Simulation Studies

Inprocess, applying both the conventional approach and the Dynamic Simulation one.

Figure 1 above shows a comparison of the predicted load by a steady state method versus the one predicted by the Dynamic Simulation for the same unit and scenario. Data are a mixture from projects executed by Inprocess and other found in the literature, A. Arbo (2008), P.L: Nezami (2008), D. Grubber (2010), Marchetti (2011), H. Chittibabu (2010), Harry Z. (2014) and M.H. Marchetti (2011).

The blue diagonal line corresponds to the fact that both loads match the same amount. Dots under the diagonal correspond to scenarios in which the steady state load is higher than the dynamic one. This means that the flare capacity is oversized by the steady state approach and, therefore, there would be a non-required investment of capital. As for the dots over the diagonal, these correspond to predictions where the steady state load was less than the one predicted by Dynamic Simulation. It can be surprising that there is a 20% of calculations where SSB relief calculations are smaller than dynamics results.

Can we sustain that relief loads calculated by SSB are always conservative?

From the above picture It can be affirmed that there are some cases (20%) where the relief load estimated by SSB could be under-sized and, therefore, that they cannot always be considered conservative.

A first though for such results is the assumption that the under-sized result responds to an insufficient competence of the engineer performing the calculation. Nevertheless, there is no evidence supporting such claim. Contrarily, there is the evidence that SSB intends to include all aspects of a highly transient behavior, such as the one occurring during a relief scenario, into an unbalanced heating duty and a latent heat, which is the base of the SSB methodology. Thus, it should not be unexpected that sometimes they undersize the relief load.

Which reasons explain that SSB can lead to oversize or undersize the relief load as shown in figure 1?
Relief scenarios are impacted by

- The process composition and flow changing during the transient
- The size of the equipment (hydraulics, process gain and time response)
- The equipment performance as a function of the two abovementioned factors

These two factors are unique for each case and as they are not taken into consideration by the SSB methods, the calculation of the relief load could potentially result in an inaccurate sizing of the required area, either being oversized or undersized.

However, inputs of a dynamic simulation model based on the first principle are the pressure boundaries, the Inlet temperature and composition and the Size of equipment. Additionally, the outputs of the simulation are the pressure, temperature, flow

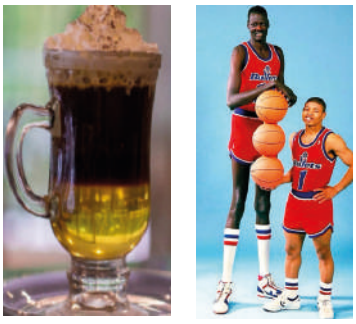

Figure 2. Impact factors during the relief scenario

and composition profiles along the unit during the transient. Therefore, unlike the SSB, dynamic models could successfully include all the aspects that occur during a relief scenario and provide a rigorous calculation of the relief load.

In any case, what happen when we realize the installed area is not enough to protect the unit? the specialized engineers could be ready to propose alternative mitigation measures like a SIL 3 for stopping the feed, the steam to a reboiler or the fuel to a furnace. In this sense, for the SSB methods nothing changes as such tripping actions cannot be assumed to be instantaneous and, accordingly, the previous worst-case scenario must be kept into consideration. Contrarily, dynamic simulation indeed could take into account the impact of such measures and show that, in such a case, the installed area is enough to protect the unit.

Thus, by applying dynamic simulation, it is possible to create a detailed model of the process unit and the dynamic phenomena that occur during the relief event and develop a realistic understanding of the overall relief behavior of the plant. The advantages of applying dynamic process simulation for relief load studies compared to the SSB are the better estimation of maximum flare load, the better assessment of simultaneity of different peaks and the analysis of effectiveness of planned measures, such as control and Safety Valve resizing.

How much is the effort required to perform a Dynamic Model of your Unit?

Dynamic simulation allows you to include as much detail as you like for your plant. But not all the details are required to estimate the Relief Load. Here is where you need a solid understanding of your plant as well as deep process and modelling skills. The success of a reliable estimation of your relief with the minimum effort is based on having a team of experts that fulfill such mixture of competences. Plant operators and operator engineers of the plant plus dynamic simulation experts should be the fundamentals of such team.

Additionally, the improvements in hardware technology in the last 10 years have reduced significantly the time required to conduct dynamic studies and they are much more affordable now.

Besides that, Digital Disruption into the Chemical Engineering Industry is providing a wide number of helpful applications. Two of them are digital twins and Operator Training Systems, OTS, which could also be holistic dynamic models based on first principles. With a Previous verification of the adequacy of the digital twin or OTS model assumptions, these models could be adequate to be used to understand what is going on during an expected event of your plant like a wide side power failure or a reflux pump trip, providing accurate estimations of the relief load for such scenarios or others. The benefit of having these models already available is saving all the effort invested on building the dynamic model itself.

So, as a bottom line of this technical note, it has been shown that contrary to the well-known statement that SSB are conservative, they are not at all. Composition changes together with the size of the equipment are not considered by SSB methods, giving a lot of uncertainty to the relief estimation. The availability of dynamic models based on first principles, thanks to the digital disruption together with a skilled team of experts could also disprove the topic related to the effort of having a dynamic model available. For the presented reasons, the two main justifications used by the industry not applying dynamic simulation for a rigorous estimation of the relief loads are not anymore valid.

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