Deciding System Flare MDMT

Depressurization setting flare MDMT

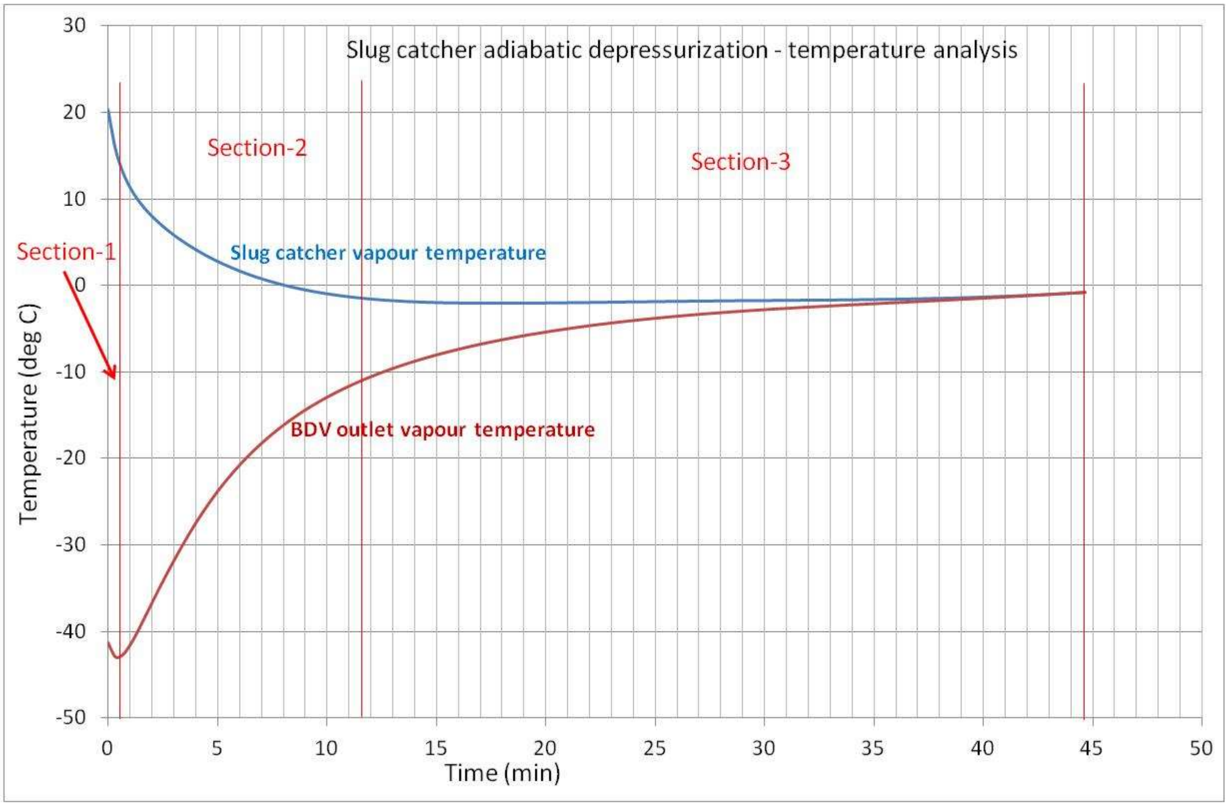
Minimum design metal temperature of High Pressure (HP) flare system is a decision that every oil and gas central processing facility (CPF) designer has to make. In absence of any low temperature system (if NGL is not recovered), flare MDMT is typically set by unintended depressurization/blowdown of the facility i.e. so called cold or adiabatic depressurization.

Depressurization is a dynamic event where process system pressure drops with time. Process system temperature also continues to drop as a result of near-isentropic expansion. Flare system also has its own dynamics, where pressure builds-up in the flare system. Temperature of flared gas thus varies with time due to changing P/T profile of process system as well as changing pressure profile in flare system and J-T expansion across BDV/RO.

HYSYS depressuring utility predicts pressure/temperature profile of process system as depressurization proceeds. For given fixed backpressure, temperature of flared gas as it exits BDV/RO is also predicted.

Minimum temperature of "Vapour-out" stream is typically used for deciding MDMT of flare system. This post details as to how this can be overly conservative and how low temperature carbon steel can be retained as HP flare MOC instead of costly Stainless Steel.

Figure below shows temperature of vapour in and downstream of BDV for a typical CPF slug catcher system.



As can be seen from above figure, process system vapour temperature continuously drops due to isentropic expansion of gas. As time progresses, curve tends to flatten out as heat gain from ambient balances temperature drop due to pseudo-isentropic expansion.

Flared gas temperature is decided by interplay of two mechanisms:

- Process system temperature drop due to pseudo-isentropic expansion
- Flared gas temperature drop due to J-T expansion in BDV/RO

Based on dominant mechanism of the two listed above, shape of flared gas temperature profile can be seen to consist of three sections:

- Section-1: Initial drop section
- Section-2: Rising section
- Section-3: Final flat section

Section 1 – Initial drop section

Section-1 has sharp drop in flared gas temperature. This is predominantly due to J-T effect of gas and has little to do with process system temperature drop due to isentropic expansion. Backpressure is almost nil and hence J-T effect is at its maximum.

Minimum temperature attained in this step does not depend on rate of depressurization or system area or system volume. It depends only on starting temperature, process system pressure, flare backpressure and composition of gas (affects J-T coefficient of gas).

Low starting temperature, high process system pressure and low flare backpressure give lowest flared gas temperature.

J-T coefficient of gas can be estimated from simulator by ratio of temperature drop and corresponding pressure drop. Table below has J-T coefficient for streams:

System	MW	J-T coefficient (K/bar)
Slug catcher gas	20.9	0.51
Gas-2	21.6	0.605
Gas-3	29.1	0.74
Gas-4	33	0.82

As can be seen from above table, heavier the gas, larger is J-T coefficient and hence larger is temperature drop at the start of depressurization.

This decreasing trend of flared gas temperature in section-1 is of short duration as pressure in vessel continues to drop with time and backpressure develops in flare header. This makes flared gas relatively warmer with time. Figure above indicates minimum temperature of flared gas in section 1 as -43 deg C and is based on HYSYS utility run with 0 barg backpressure.

Flarenet analysis with peak blowdown rate gives actual backpressure of 5.1 barg. HYSYS depressuring utility with this backpressure gives minimum temperature of flared gas as -35 deg C.

With Mach number of flared gas in header of about 0.15 (velocity of about 50 m/s), backpressure would develop in around 42 seconds (time it takes for pressure pulse to reach flare tip). A simple dynamic analysis indicated about the same time for backpressure to develop.

Few conclusions can be derived for this section:

- Minimum temperature reached by flared gas in this section solely depends on gas molecular weight, initial temperature and pressure
- Heavier gas would decrease flared gas temperature
- Minimum temperature as indicated in HYSYS depressuring utility with 0 backpressure would last only for few 10s of seconds

This low temperature for few seconds would not even bring BDV outlet pipe to low temperature due to large thermal inertia of the system.

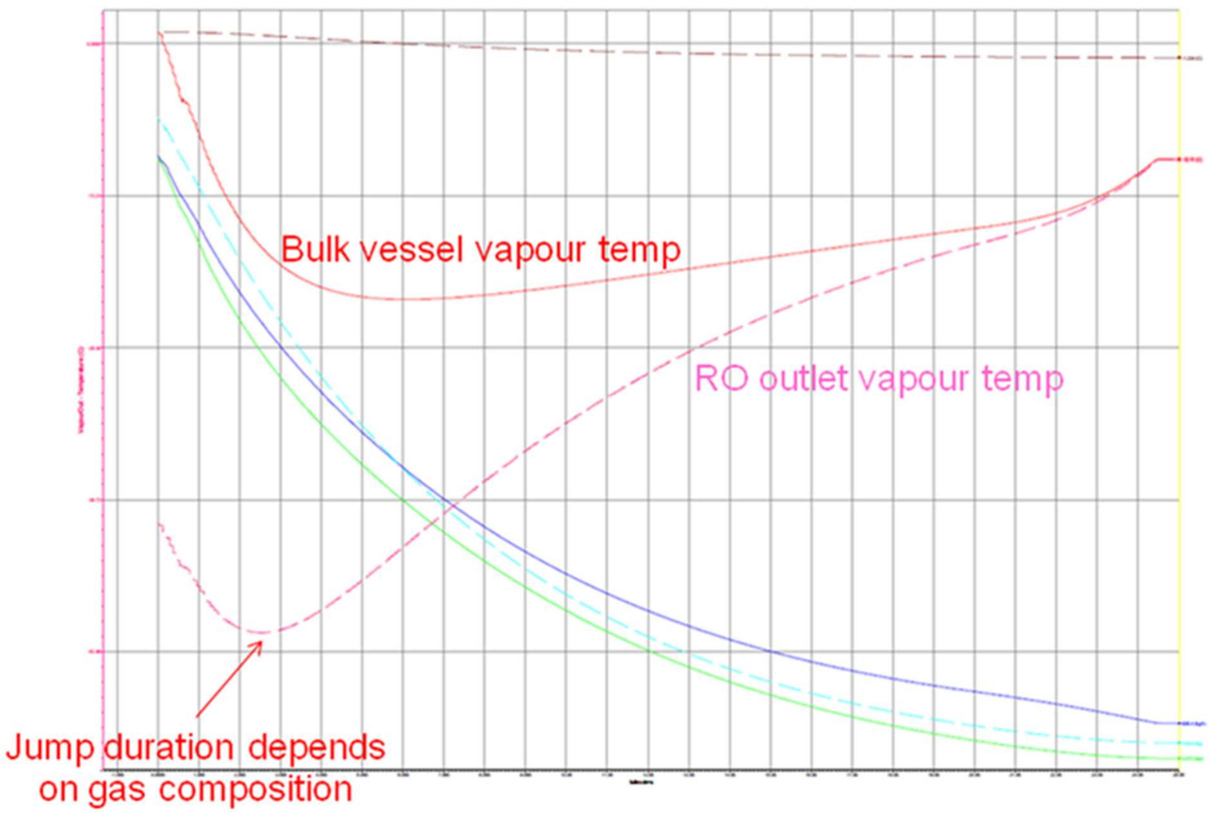
Section 2 – Rising curve

Section -2 has rising curve for BDV outlet temperature. This section witnesses drop in vessel temperature due to isentropic expansion of gas. J-T expansion in BDV is negatively affected due to drop in pressure, but helped due to drop in BDV inlet temperature due to depressurization. Net BDV outlet temperature depends on extent of these opposing effects.

For higher molecular weight gases, isentropic coefficient is low and hence drop in system temperature is much lower compared to lighter gas. But for higher molecular weight systems, J-T coefficient is higher giving higher temperature drop for same pressure reduction compared to lighter gases.

For system in above figure, isentropic expansion does not decrease temperature enough and hence after initial drop BDV outlet temperature sharply increases.

For lighter gases, isentropic temperature drop in vessel is much significant and hence this more than compensates for decreased J-T effect due to decreased pressure. This leads to lower temperature at BDV outlet for longer duration of time with BDV outlet temperature rising curve section much later during depressurization. Curve below shows temperature profiles for gas with molecular weight of about 17:



Section 3 – Flat curves

Section-3 has both slug catcher vapour and BDV outlet temperature approaching each other. Isentropic temperature in vessel shows increasing curve due to heat gain from ambient. Temperature drop in BDV due to J-T effect is also not significant due to low pressures.

In summary, analysis of these curves show that BDV outlet temperature drop is only momentary. For conservative design, MDMT of HP flare header is considered as -46 ^{o}C. Flare header material of construction is selected as Low Temperature Carbon Steel (LTCS).

Risks:

- Liquid entrainment
- Staggering depressurization
- Sweating of vessel wall leading to no flattening process system temperature with time
- Variation of Cd with time