JM ProcessWise Webinar
Hazards of low rate SMR operation
June 2020

Questions and Answers

Q1. How does excess air affect flame shape and is there a limit?

A1. Insufficient excess air can create more turbulent flames, it may cause after-burning and can causing fouling of burner tips. These issues all increase the risk of flames impinging on the tubes and burner damage. At low rates, having a slightly higher than normal level of excess air can help maintain good distribution of the air and thereby maintain good flame shape. Running with higher levels of air will however reduce overall plant efficiency and cause longer flames, but this is not likely to be a concern at low rate. It may also impact plant NOx emissions.

Q2. What do you consider a good TWT distribution, do you have some advice for balancing a reformer and are there any instruments other than a pyrometer to measure TWT?

A2. Most operating plants can achieve a tube wall temperature spread of less than 100°C/180°F. Most plants use handheld IR pyrometers to measure the TWT, although there is increasing use of thermal imaging cameras. Fixed installed cameras are also now available for continuous monitoring of the reformer TWT's. There are also pseudo contact pyrometer's, such as Johnson Matthey's Gold Cup pyrometer, that can provide a more accurately measure of TWT for troubleshooting requirements. For effective balancing of the reformer it is important to ensure your pyrometer is routinely calibrated, TWT measurements are recorded, only small step changes are made to the reformer and sufficient time is given to the reformer to re-equilibrate before re-assessing the TWT's and making the next change. Providing appropriate training and guidance to your operators for this purpose is important.

Q3. Does low rate operation affect the location of carbon formation and if there is carbon, what should we look for?

A3. The carbon formation region may move slightly towards the tube inlet at low rates, however generally carbon is still most probable at the 20-40% zone of the tube length. Whenever the reformer is operated at abnormal operating conditions, it is advisable to make frequent visual assessment of the reformer tubes. Attention should be paid to signs of flame impingement, hot zones in the reformer and signs of hot spots/patches.

Q4. What is a hotspot and can you tell the difference between hot spots caused by poisoning and carbon formation?

A4. Hot spots caused by poisoning and carbon formation can appear very similar in appearance. Any occurrence requires a root cause analysis. Slip of sulphur from the purification section should be conducted to assess for poisoning and a review of operating data to check for accidental operation at low steam to carbon rations.

Q5. What factors affect the methane slip, how do you calculated approach to equilibrium (ATE) and how does low rates affect conversion?

A5. Methane slip is a function of feed flow, feedstock composition, temperature, pressure, catalyst activity and S:C ratio. ATE is calculated by measuring the outlet methane slip and comparing the catalyst exit temperature to the equilibrium temperature for the same methane slip. At fixed operating conditions, the ATE is an indication of the catalyst activity.

Q6. How do low rates affect different reformer designs?

A6. Most reformers have a minimum turndown of 40-50% plant design rate, this is to maintain a reasonable distribution across the process, fuel and air headers. In top fired reformers complex inlet and outlet headers are required in order to maintain uniform distribution of process gas to the tubes, fuel and air to the burners and to collect the flue gas across rows of tunnels. In a side fired or terrace wall reformer the challenge is to maintain uniform process gas distribution between the two cells and along the tube row, which would have a larger number of tubes per row than an equivalent capacity top fired reformer. A side fired reformer also has more burners that need to be managed, with the added complexity of a varying draft pressure in the radiant section due to flue gas upwards flow.

Q7. Why does the flue gas go downwards in a top fired reformer and how can you tell if you have maldistribution of the flue gas?

A7. The flue gas in a top fired reformer flows downwards as it is designed with flue gas collection tunnels at the floor which remove the flue gas from the radiant box directing it into the convection system, in which there is an induced draft fan. Mal-distribution of flue gas can be identified by observing the direction and turbulence of the flames and may be observed from a pattern in the TWT's measured. A dry powder injection test can also be conducted through the burner ignition port to better observe the flow direction of the flue gas.

Q8. How is fuel affected at low rates and how should burners be managed?

A8. Relative heat loss is higher at low rates. As mentioned in the webinar, it can also be useful to operate at higher S:C ratios and higher excess air ratios at low rates. With these effects fuel turn down may not be linear to plant load. Trim fuel is always added to purge gas to maintain steady operating conditions. It is normally preferable to reduce the fuel pressure to all the burners, rather than isolating individual burners, however there may be occasions when isolating individual burners is desired, e.g. to manage a hot tube. Burner operating procedures significantly vary depending on the burner design and therefore the flexibility in operating modes of the burners should be discussed with the burner supplier.

Q9. At what conditions would preferential flow issues happen?

A9. Most reformers have a minimum turndown of 40-50% plant rate to prevent maldistribution issues.

Q10. What correlation does the pressure drop have to even distribution of process gas in the tubes?

A10. During the catalyst loading, the pressure drop across each tube will be checked. A pressure drop between tubes of ± 5% is normally expected. Often ± 3% can be achieved especially with semi-automated loading techniques. A high pressure drop across the reformer during operation is an indication of a restriction in flow. If the restriction is only within a few of the tubes, then this will cause maldistribution of process gas.

Q11. What is the impact of low rates on the other units?

A11. Maldistribution of process gas can also occur at low rates in adiabatic units, such as the purification or WGS beds. This is influenced by the bed geometry, distributor design, collector design and catalyst/absorbent size. Greater care is required for radial bed designs.

Q12. Why should S:C ratio be increased at low rates, what is the optimum S:C ratio at low rates and how long can you operate on steam alone?

A12. The optimum S:C ratio tends to be governed by the flowsheet. Factors include the balance between conversion, prevention of carbon formation and maximising plant efficiency. At low rates there is an increased risk of maldistribution of both the process gas and of the heat distribution in the radiant box. Consequently, increasing S:C ratio at low rate helps improve the distribution of process gas, aids in preventing high TWTs and it also increases the margin for carbon formation. Your catalyst supplier can advise how long you can operate your reformer catalyst at high S:C, as effects can vary depending on the catalyst types.

Q13. Is there a lower limit on operating temperature?
A13. The methane slip increases as the reformer exit temperature reduces. This is due to the difference in equilibrium position and lower temperatures slowing the reaction rate across the catalyst. The minimum outlet temperature is determined by the maximum methane limit for the downstream operations and the impact on heat integration.

Q14. Why for lower plant rates do you recommend lower system pressure?
A14. Reducing the pressure reduces the gas density, which helps to increase velocity in the reformer tubes, thus improving heat transfer and gas distribution. It also reduces the chance of tube damage if overheated.

Q15. How can you determine how much heat loss you have?
A15. The heat loss from the reformer can be calculated by modelling the energy balance around the unit, which requires the heat input from the fuel, the expected heat demand from the process and the process conditions. For the calculation of temperature loss at the outlet of the reformer, it is possible to assume the water gas shift reaction will be at equilibrium at the exit of the reforming catalyst. Provided you can complete an accurate heat and mass balance around the reformer, it is possible to calculate the WGS equilibrium temperature for the wet gas composition. The difference between this temperature and the measured reformer exit temperature provides the temperature loss.

Further Information

Please contact your local Johnson Matthey representative for further information or send your enquiry to polly.murray@matthey.com