Efficiency improvement by feed forward control

SRU plants often process gas of unknown and fluctuating compositions coming from a variety of process units in a refinery. Feed forward control is key to handling these fluctuations.

One of the difficulties process analyser manufacturers face is the measurement of unknown process gas compositions. The other challenge is that the measurement must be very fast. The process gas needs to be measured right at the inlet of the Claus reaction furnace. The reaction time of the process gas in this reaction chamber is around three seconds, so any measurement taking longer becomes useless. In addition, ensuring the safety of refinery operating personnel is of paramount importance as the gases being measured can potentially contain up to 90% hydrogen sulphide (H_2S), one of the most toxic gases in a refinery. Having a simple, easy to understand and operate sampling system eliminates human errors and improves safety.

AMETEK Process Instruments has introduced a measuring system which meets these challenges, providing fast, reliable and safe measurement of process gas streams with unknown composition. End user feedback has confirmed its value with several users of this feed forward analyser reporting, "We decided to install this analyser in order to mitigate upsets of our SRU plant, in the beginning we were looking at the appearance of upsets, but now we have found the instrument is also useful for showing the disappearance of the upset condition as well".

Process upsets

The TGTU operation of a sulphur plant depends on a smooth operating Modified Claus unit, but unless the SRU is handling a stable acid gas, e.g. in a small scale natural gas treatment plant, this is often not the case.

Unusual process conditions (upsets) are never welcome and shouldn't be considered as "normal" but in daily life they happen, particularly when processing different acid gas streams or sour water stripper gas in the SRU. What is important is how well the situation can be controlled.

In some cases an upset may cause loss of recovery efficiency, resulting in higher emissions, which is undesirable but manageable, but in other cases, in addition to increased emissions, there may also be damage to process units. The latter can be caused by the breakthrough of hydrocarbons. Table 1 illustrates the impact of hydrocarbons on the air demand.

The higher oxygen consumption from the hydrocarbons will result in an air deficiency, which will be measured by the tail gas analyser and fed back to the process control system but only after a time delay (process lag time). Furthermore, the tail gas analyser only controls the trim air to the Claus reactor. If this is not enough, knowing about the condition of the upset will help.

Unfortunately, an accurate and component specific measurement is not possible in the required time. These measurements are only possible with the use of process gas chromatographs which take around 5+ minutes from the change of the process gas to any result of measurement (this includes sampling system). The upset may also be over before it is reported.

Table 1: **Impact of hydrocarbons on air demand**

Compound	Moles O_2 per mole HC	Ratio of O_2 needed per mole HC compared to mole of H_2S
Methane	2	4
Ethane	3.5	7
Propane	5	10
Butane	6.5	13
Pentane	8	16
Hexane	9.5	19

Source: AMETEK

In the worst case scenario, hydrocarbon breakthrough, i.e. when there is insufficient air to burn the hydrocarbons, may lead to soot formation in the first catalytic reactor. Other consequences include loss of recovery efficiency leading to higher sulphur emissions.

The TGTU will be forgiving and correct for the appearance of hydrocarbons. As an increase of hydrocarbons in the feed gas will lead to an air deficiency, the H_2S concentration in the tail gas will increase. However hydrocarbons can disappear as fast as they appear. The control system may have just managed to adjust the air flow to the reaction furnace so that everything is back to the required control set points but if the hydrocarbons then suddenly disappear there will be too much air fed to the reactor which will increase the SO_2 concentration in the tail gas to unacceptable levels. The important question now is whether there is enough hydrogen available to hydrolyse all of the SO_2 into H_2S. The following CoMo catalysed reactions take place in the reducing reactor:

$$SO_2 + 3H_2 \rightarrow H_2S + 2H_2O \quad (3)$$

$$S + H_2 \rightarrow H_2S \quad (4)$$

$$H_2O + CO \rightarrow H_2 + CO_2 \quad (5)$$

$$COS + H_2O \rightarrow CO_2 + H_2S \quad (6)$$

$$CS_2 + 2H_2O \rightarrow CO_2 + 2H_2S \quad (7)$$

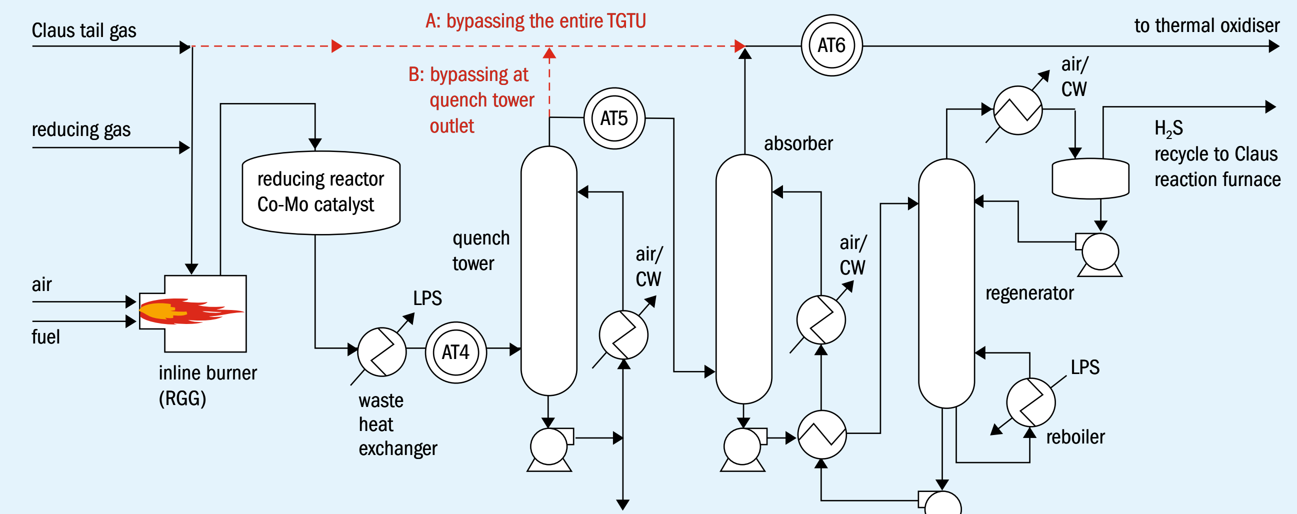
Any SO_2 breakthrough into the absorber tower will cause irreversible damage to the amine, which can be quite costly (costs of $40-50 per litre are not uncommon for specific amines). In this scenario, bypassing the absorber is the only option. There are two bypass options:

- bypassing the entire TGTU
- bypassing at quench tower outlet

Both options are illustrated in Fig. 2.

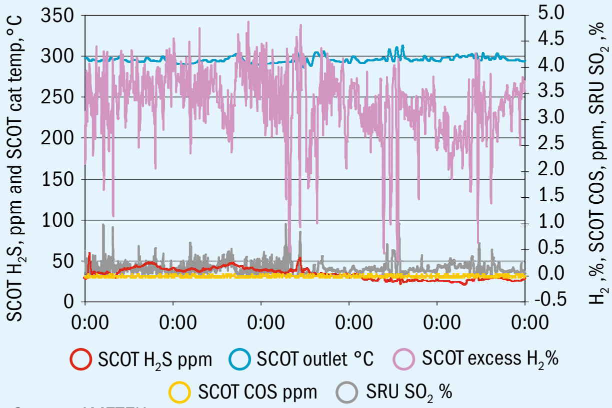
Process gas analysers (AT4, AT5 and AT6) can help to mitigate the worst case scenarios of 1) damage to the absorber

Fig. 2: **Bypass options in the tail gas treatment process**



Source: AMETEK

Fig. 3: **Example of SO_2 breakthrough**



Source: AMETEK

amine and 2) bypassing the TGTU for an extended period of time.

In some plant setups both measurement options are utilised in the TGTU. AT4 monitors SO_2 concentrations, to prevent damage to the amine found in the absorber. AT5 measures the H_2S concentration entering the absorber, to quantify the amine load required. AT6 measures the H_2S (and potentially COS and or CS_2) concentration to assist in isolating operational problems and quantify contributions to sulphur emissions.

Recall that the reduction reactor in the TGTU converts all remaining sulphur components carried over from the modified Claus to H_2S, which is removed by the absorber and recycled to the Claus reaction furnace. In order for these reactions to take place, a reliable supply of hydrogen is required.

The graph in Fig. 3 shows the H_2 reading as a function of an SO_2 excursion. As soon as there is a deficiency of H_2, SO_2 breakthrough becomes likely. Looking more closely at the reactions taking place in the reducing reactor (equations 3-7) it can be seen that every mole of sulphur also consumes one mole of hydrogen. As such, presence of SO_2 at AT4 indicates that the hydrogen feed should be increased. Some users will monitor hydrogen at this point (or at AT5 or AT6), to identify whether or not too much hydrogen is being injected.

Proper selection, installation and operation of process analysers can reduce emissions, safety risks and operational costs in SRUs.

SRUs have historically been complex to operate because of the varying make-up of the feed gas streams and the multiple thermal and chemical processes used to remove elemental sulphur, but AMETEK analytic solutions continue to reduce that.